International Emissions Trading

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International Emissions Trading: Design and Political Acceptability

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Foreword

According to Søren Kierkegaard, life can only be understood backward; but it must be lived forward. Much the same is true for a dissertation; you start writing it, but first at the end you fully grasp what it is all about. Fortunately, several people have helped me on the way, both with the writing and the understanding, and some with both.

I started my academic career as an assistant for Andries Nentjes and continued with writing my PhD thesis under his supervision. What I have appreciated most in Andries during all these years is his openness to new ideas, even if they contradict his own ideas. Besides that, he gives one an opportunity to pursue these ideas, also when they divert from the original research plan. I want to thank Andries for giving me those opportunities and for allowing me to follow my heart to distant places. Most of all, I thank him for giving me new inspiration at times when I had lost faith in the project.

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Contents

Chapter 1

Introduction

The earth's atmosphere traps incoming heat from the sun such that, on average, we bath in comfortable temperatures, instead of constantly freezing. This greenhouse effect, as it is called, has been known for quite some time (Fourier 1827; Arrhenius 1896) and depends on the concentration of amongst others carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) in the atmosphere. The greenhouse effect first became a policy issue in the 1980's when it was found that temperatures had risen rapidly on earth during the past century. The main hypothesis for the cause of this was an increase in greenhouse gases (GHGs) in the atmosphere caused by human activity, mainly the burning of fossil fuels. In order to assess the risk of human-induced climate change, the Intergovernmental Panel on Climate Change (IPCC) was establishment in 1988. During the 1990's it was shown convincingly that global warming is caused by human activities.

In order to tackle global warming negotiations on an international climate change agreement were started, resulting in the United Nations Framework Convention on Climate Change (UNFCCC) signed in Rio de Janeiro in 1992. Here, the industrialized countries promised to make efforts to stabilize GHG emissions at their 1990 level by the year 2000. There was however no commitment to specific emission levels. These came in 1997 in Kyoto where the Annex B countries (the industrialized countries) agreed on a reduction in GHG emissions from the Annex B countries in CO_2 equivalents of 5.2

percent in the commitment period 2008-2012 relative to 1990. The abatement commitments were differentiated between the Annex B countries with the EU promising 8%, the US 7%, Japan and Canada 6% and the Russian Federation a stabilization of emissions relative to 1990. In March 2001, the USA withdrew from the Kyoto Protocol. However, the ratification of the protocol by the Russian Federation in 2005 meant that agreement was effectuated.

One of the major problems in combating global warming is that the costs of reducing emissions of greenhouse gases are very high and fall in the presence, while the major beneficial effects of reduced global warming will first arise in the far future. Hence, reducing costs of emission reduction should be one of the main concerns in the design of a climate change agreement. According to economic theory, costs of achieving a given level of emissions are lowest when the marginal abatement costs between emission sources are equalized (Baumol and Oates 1988). Since abatement costs normally differ between countries, one step toward marginal cost abatement is to differentiate abatement commitments between countries. But even though the abatement commitments in the Kyoto Protocol are differentiated, they by no means ensure that the total emission limit is reached at lowest costs. To reduce the overall costs of committing to the abatement obligations, flexibility instruments were already introduced in Rio de Janeiro in the form of Jointly Implemented activities. In the Kyoto protocol, these were expanded to four instruments: the Bubble (Art. 4), Joint Implementation (JI) (Art. 6), the Clean Development Mechanism (CDM) (Art. 12) and International Emissions Trading (IET) (article 17). The first instrument, the Bubble, allows groups of countries to meet their abatement obligations jointly. This was especially created for the EU, so that it could negotiate as a single party, while it was still possible to differentiate the total burden between the EU countries, as was done later in the burden sharing agreement. JI and CDM are both project-based instruments, where a baseline of emissions has to be estimated per project and emission reductions are measured against this baseline. The main difference between JI and CDM is that JI can only take place between two countries that have committed to an emission ceiling in the period 2008-12, while with CDM, the host country is a non-annex B country. IET can only take place between Annex B countries and amounts to a transfer of greenhouse gas quotas between countries.

As such, JI and IET were not immediately embraced by all countries. Especially the EU was sceptic about the flexibility mechanisms (Ringius (1999)). One of the main reasons for this scepticism was that emissions trading in its various guises was seen as a loophole for countries that did not wish to reduce emissions domestically. Furthermore, for several countries, notably the Russian Federation and Ukraine, the emission commitment under the Kyoto Protocol was such that their expected emissions in 2008-2012 were lower than their emission ceiling. IET makes it possible for these countries to sell emission quotas without having to reduce emissions. This trade in 'hot air', as it is called, will increase total emissions in the period 2008-2012 relative to when such trade is not allowed. Many proposals have been made since on how to reduce the effect of hot air trading (see Woerdman (2002), pp. 139-144 for an overview). That especially IET has made it to the Kyoto Protocol is mainly thanks to the position of the US. They made it clear they would only accept an agreement which included international emissions trading. Even though other countries eventually accepted this demand, the US has not ratified the Kyoto Protocol.

In the Kyoto Protocol, the flexibility mechanisms are only sketched roughly and subsequent Meetings of the Parties have clarified only a part of these issues. Therefore, details of the design and functioning of the flexibility mechanisms still need to be worked out. For IET, some of the questions are whether only governments are allowed to trade, or whether private parties can trade too, and in the latter case whether countries have to implement tradable permits as a prerequisite for international trade between private parties or whether international emissions trading also can be based on other national instruments.

In order to comply with the commitments in the Kyoto Protocol, the EU has implemented its own emissions trading scheme (DIR 2003/87/EC). The scheme comprises four major sectors[1] with a total number of about

[1]Energy activities, iron and steel industry, mineral industry and pulp, paper and board

11,000 installations. Initially, the scheme only covers CO_2 emissions from these sectors, but it may be enlarged to cover other GHGs and sectors. All installations covered are given an initial endowment of permits mainly through grandfathering, i.e., they receive them for free, although a small part of the permits can be auctioned off by the government. Hence, the scheme is one with a cap on total emissions. Since the EU is a party in the Kyoto Protocol, the EU emissions trading scheme does not classify as IET under Kyoto Protocol Art. 17, but as a domestic instrument. However, from the point of view of the EU member states, it is international emissions trading. The EU scheme commenced on January 2005 and has two trading phases; the first that runs from 2005 to 2008 and the second that runs parallel with the Kyoto commitment period of 2008-2012.

Prior to the implementation of the EU scheme a discussion on the design of an EU emissions trading scheme was taking place, initiated by the European Commission. Proposals put forward showed that there are several possible ways to organize emissions trading between private parties. Proposals by member states on how to organize emissions trading within the EU also contained different designs, and in certain cases there were even proposals with a different design for different sectors (see CO2 Trading Commission 2002). Industry also lobbied with the European Commission perhaps mainly in the hope of being held outside the scheme, but also to affect the design of the scheme.

It is clear that international emissions trading is not equally acceptable to all, be it nations, sectors of industry or other interest groups. The acceptability of IET will be dependent on several factors such as its effect on total emissions, its effect on welfare and the distributional effects of the scheme. These factors are partly influenced by how international emissions trading takes place, i.e. the design of the scheme. In this book, we will analyze some aspects that affect the acceptability of international emissions trading.

A first issue is how international emissions trading affects the abatement target countries set, which is the subject of chapter 2. International emissions trading changes the costs of emissions for the participating countries.

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industry

A high cost country can buy emission quotas in the market to cover its emissions at lower costs. It can now afford a higher abatement commitment since it can buy emission reductions at relatively low costs. On the other hand, a low cost country, which is a potential seller of emission quotas, will want to set a lower abatement commitment since setting a higher emission ceiling implies that it can sell more quotas. But when both low and high cost countries change their abatement commitment when faced with international emissions trading, total world emissions are likely to change too. Together, the change in abatement commitment and the change in total emissions of the group of countries involved affect welfare for the single country. As we will show, it is not certain that this effect is always positive. The change in national welfare will, at least for welfare maximizing countries, influence countries' position on whether international emissions trading should be allowed or not.

When international emissions trading is accepted, the next issue is how the scheme could be organized. In chapter 3[2] we will present several possible designs for international emissions trading. Basically, international emissions trading can be organized either as trade between governments or as trade between emission sources. With government trading, international emissions trading amounts to a transfer of national quotas from the seller to the buyer country, so that the national emission ceiling becomes higher for a buyer and lower for a seller. After the trade, the countries involved have to adjust their national policies accordingly.

International emissions trading between emission sources can be organized in several ways. The basic issue here is the national design of emissions trading. International emissions trading can then be organized by linking the national emission trading schemes with each other. For this it is not necessary that all countries choose the same form of private emissions trading. One possible design for emissions trading between private actors is to put a cap on total emissions and to divide this cap over emissions sources in the form of permits. Sources are than allowed to trade permits with

[2]A previous version of chapter 3 has been published as Boom and Nentjes (2003)

each other. This is the classical textbook case of tradable permits[3] which in this book will be denoted by permit trading. Permit trading can be organized in several ways, depending on who is regulated (emission sources, or suppliers or distributors of fossil fuels), and on whether all or only some sectors are covered by the scheme. Alternatively, instead of a cap and trade scheme, one could impose some other emission standard and allow the sale of emission reduction credits when firms can stay below the emission target defined by the standard. We argue that the emission standard will be a relative standard that limits emissions per unit of some input or output. In this book, this type of emissions trading is modeled as trading based on an emission standard per unit of output, and is denoted by credit trading throughout. Permit and credit trading have quite a different impact on the regulated industry. In general, credit trading leads to higher output and higher abatement costs than permit trading.

After the introduction and overview of several types of emissions trading in chapter 3, we will focus on permit and credit trading in the remainder of the book. First, in chapter 4, we will give an analysis of permit and credit trading under both perfect and imperfect competition on the product market in a national setting. The question to be researched is how the two types of emissions trading under the distinct market structures affect welfare and other economic variables. We analyze both the short run effect where entry and exit are not possible and the long-run effect where entry and exit are possible. Hence we are able to show the difference in impact on total and firm output, on prices and on the number of firms in the industry. Credit trading turns out to be an inefficient instrument under perfect competition. However, under imperfect competition it may outperform permit trading. Permit and credit trading can also be combined. By this we mean that two sectors or countries can be regulated with a different type of emissions trading. Trade between these two sectors is then possible by linking the two markets. In chapter 4 we give an analysis of combining permit and credit trading and show its effect on the two regulated sectors.

[3]See Baumol and Oates 1988; Hanley et al. 1997; Kolstad 2000; Tietenberg 2003 or Perman et al. 2003 for an introduction

In chapter 4 it is, implicitly, assumed that all actors, i.e., government and industry, are rational, have complete and perfect information and perfect foresight. When introducing environmental regulation, this makes it possible for the government to set regulation at its long-run equilibrium level. At the same time, entry or exit to the industry happens at such a level that the new equilibrium number of firms is attained instantaneously. Furthermore, firms adjust to the new regulation by adjusting their production and emission levels so that they also are in their new long-run equilibrium. But suppose that the government and industry do not have such information and foresight, how would that affect the outcome? In chapter 5 we give a discrete time model where we use some other assumptions on the behavior of governments and firms than the ones stated above. Specifically, in chapter 5 we assume that firms react instantaneously to regulation by adjusting their output and emission level. However, entry and exit of firms is based on profits of firms in the sector in the previous period. For the government, two types of behavior are given. The government can react myopically, in which case it sets environmental policy with the assumption that firms do not adjust output and that entry and exit do not take place. It can also have perfect foresight and perfect information, in which case it sets the equilibrium policy from the start of regulation. We show that with myopic behavior by the government credit trading can lead to sustained volatility in the regulated sector under both perfect and imperfect competition. With persistent volatility, the industry never reaches a new equilibrium and output, prices and emissions fluctuate over time. When the government has perfect foresight, it sets optimal policy from the start. In that case, persistent volatility is only observed under imperfect competition.

In chapters 6 and 7 we again assume perfect and complete information and perfect foresight by the government and immediate adjustment of firms to prices. Both chapters give models with international trade in the goods market. We assume the existence of an international emissions quota market that the government can allow its firms to participate in. In these two chapters we analyze whether a welfare maximizing government prefers permit or credit trading as national instrument when it has market power in the international goods market and whether it wants to allow its firms to participate in international emissions trading. In chapter 6 we present the case where the regulated industry is perfectly competitive, while in chapter 7 we assume that there is an international duopoly with one firm per country. When a country has market power on the international goods market, it will have an incentive to manipulate the price of the good to improve the welfare of the home country, even though this will reduce welfare abroad. Here, we assume that the government cannot affect the price of goods directly, e.g. through import and export duties, and also that it has committed to a specific national emission target, so that the only way it can manipulate industry's output is through its choice of instrument of environmental policy. As mentioned above, permit and credit trading have a different impact on industry output and hence, in this setting, the government may prefer a different instrument in different circumstances. We show under which circumstances a government prefers credit or permit trading and that in certain cases it prefers not to allow its firms to participate in international emissions trading.

In chapters 2 to 7 we assume a government that maximizes national welfare. This allows us to show that under certain circumstances, a government should choose permit trading while in other cases it should choose credit trading. The word 'should' in the previous sentence already indicates that the analysis in chapters 2 to 7 has a normative character. Here we mean normative in the sense of: if the government has the objective of maximizing welfare, then it should act according to the conclusions derived from welfare economics when the assumptions underlying welfare economics are present in reality. It is a welfare economic analysis in that it shows which policies are optimal for the government to implement. However, this does not imply that governments in the cases that were presented actually will use the instrument that is optimal. The question then is why this happens, which forces are responsible, which policy objectives they want to promote and what instruments are likely to be implemented and why. These question are dealt with in chapters 8[4] and 9[5] by the use of public choice theory. Public choice is the economic study of non-market decision making, or the application of economics to political science (Mueller 1989, p. 1). As in economics, it is assumed that the economic agent is a rational, self-interested utility maximizer. This also implies that all actors involved in the decision on which instruments to implement in environmental policy first and foremost want to maximize their own utility. So politicians do not maximize national welfare, but their own utility under certain constraints, such as a fair chance of being reelected. It should be noted that public choice theory does not say that efficiency considerations are necessarily unimportant. They are however not the only considerations of importance.

In chapters 8 and 9 we assume that interest groups can influence policy decisions by politicians. For environmental policy the relevant interest groups are: the regulated firms and the organizations representing them, the labor unions and environmental organizations. We shall consider the civil service or 'environmental bureaucracy' as a group which can have interests of its own. We leave aside here how these groups can influence such decisions, but the literature gives several examples (see Austen-Smith (1997) for an overview). The first question then is how the interests of the different groups can be specified. The next question is which preferences for environmental policy instrument follow from this for the different interest groups. A third question is which of these groups are most likely to affect policy. This book focusses on international emissions trading and consequently, we are in particular interested in which instrument of international emissions trading gets the support of the strongest interest groups and therefore is most likely to be implemented. However, a preference for international emissions trading scheme can not be seen in isolation. Such a preference can be dependent on the preference for a national policy instrument. Therefore, chapter 8 gives an overview and assessment of the existing literature on interest group preference for national instrument of environmental policy. Using this as

[4]A previous version of chapter 8 has been published as Boom (2002b)

[5]Previous versions of parts of chapter 9 have been published as Boom and Svendsen (2000a) and Boom (2002a)

a basis, chapter 9 then gives an analysis of the preference for international emissions trading scheme. We show that international emissions trading is not unanimously supported, and that groups are divided over which form of international emissions trading to implement. Furthermore, there are several groups that would like to limit international emissions trading in several ways.

A summary and conclusions are given in chapter 10.

Chapter 2

The Effect of Emissions Trading on International Environmental Agreements

2.1 Introduction

In December 1997, 38 countries committed themselves to the reduction of their greenhouse gases in the Kyoto Protocol. An important feature of the Kyoto Protocol is that it allows wide scale international trade of emissions. Article 17 of the protocol states that "The parties included in Annex B (i.e. the countries that have committed to an emission ceiling) may participate in emissions trading for the purpose of fulfilling their commitments".

The article on emissions trading was included in the Kyoto Protocol after pressure by the US. Already before negotiations started, the US had made it clear that they would only commit to abatement if international trade of emissions was allowed. It was clear that the US had an interest in international emissions trading as a potential buyer. The potential sellers would be the countries where emissions could be reduced at attractively low costs, such as the Ukraine and Russia.

The result of the negotiations was that the USA agreed to reduce greenhouse gas emissions by 6 percent in 2008-2012, while Ukraine and Russia committed to keep their emission levels at the 1990 level. The latter fact was viewed with great dissatisfaction by many countries and most environmental organizations, since it was very unlikely that these two countries would reach these emission levels even without abatement measures. This created the issue of 'hot air', which means that a country can sell emissions without having to reduce emissions. In the end, the US did not ratify the Kyoto Protocol, while Russia did so after long hesitation, so that the Kyoto Protocol has come into force but will not be implemented fully.

The story above suggests that the inclusion of international emissions trading has changed the outcome of the negotiations. In this case, the potential buying country, the USA, accepted an emission ceiling, which can be stated as the willingness to accept a more stringent emission ceiling than it would have done without the option of international emissions trading. On the other hand, it seems as if the potential selling countries, the Ukraine and Russia, have negotiated higher emission ceilings than would have been the case without international emission trading.

In this chapter, we analyze how allowing international emissions trading affects the emission ceiling set by countries. We do so in a model with a global environmental problem where we compare the case with emissions trading to the one without emissions trading. In the model, countries can set their own emission ceilings and their decision will depend on the price that will arise in the permit market. We will analyze the effect of emissions trading on the individual emission ceilings of the countries involved, the effect on total emissions, and the effect on countries' welfare.

Previous work in this field includes Bohm (1992), Eyckmans and Proost (1996) and Helm (2003). Bohm (1992) analyzes the case where countries set their emission ceilings cooperatively while they are not able to influence the price of permits. The analysis is informal and restricted to linear marginal damage from emissions and constant marginal costs of abatement. Bohm finds that, in this setting, the country that will sell permits will set a higher emission ceiling when international emissions trading is possible, while the buying country will set a lower emission ceiling. Because emissions trading has an effect on wealth, it will change the demand for polluting goods, and hence affect emissions. The result of this is that total emissions may well rise when international emissions trading is allowed, compared to an international agreement which does not include international emissions trading.

In Eyckmans and Proost (1996) emission ceilings are fixed at the no policy level and countries are then allowed to trade emissions. Eyckmans and Proost assume that countries are price takers. They conclude that when countries differ in their marginal damage of emissions there will be only one buyer, which is the country with the highest marginal damage. This country in effect retires some of the permits. That is, the country will buy more permits than it will use. A major difference with the model given in this chapter is that in Eyckmans and Proost (1996) countries do not change their emission ceiling when emissions trading becomes possible, while in our model they do.

Helm (2003) discusses the case where countries set their emission ceilings non-cooperatively with countries having market power, although he does not say so explicitly. Helm shows how, in this case, the possibility of emissions trading affects a country's choice of emission ceiling and that emissions trading may lead to higher total emissions. Furthermore, Helm asserts that emissions trading may well lower a country's welfare, even in the case where total emissions decrease. In this chapter, we will show that the latter assertion does not hold. Furthermore, Helm only gives an interior solution for his game. However, such an interior solution may not exist. In this chapter, we show what the boundary solution is, and what effect it has on total emissions.

In this chapter, we will discuss three cases: 1) countries behave non-cooperatively and cannot affect the price of permits through their emission ceiling, 2) countries behave non-cooperatively, but have market power, and 3) countries behave cooperatively. In all cases, the permit market is assumed to be perfectly competitive, which would be the case if all countries leave the trading of permits to their firms.

The analysis in this paper adds to literature in several ways. First of all, it gives the first analysis of the effect of emissions trading on individual emission ceilings in the case where countries have no market power. Second, we expand the analysis by Helm (2003) to include boundary solutions and show that one of his core results does not hold. Furthermore, we show how the introduction of emissions trading affects a cooperative solution, whereas previous analysis dealt with non-cooperative models.

In section 2.2, we analyze the case where countries do not cooperate on emission reduction, but can agree on international emissions trading. First, the case where countries have no market power is analyzed, whereafter the case with market power is considered. In section 2.3 the cooperative case is analyzed. To this end, the Nash bargaining solution is used. The conclusions are given in Section 2.4.

2.2 A Non-Cooperative Model

In the analysis of the non-cooperative equilibrium, we assume that countries can make an agreement on international emissions trading, but do not negotiate on emission reduction. There are several arguments for modeling the issue in this way. First of all, there is nothing that prevents countries from trading emission permits without having agreed to a certain reduction in emissions. A group of countries that have individually set a national ceiling on emissions may simply find it beneficial to trade emissions amongst themselves. The fact that it has not occurred so far does not imply that it cannot occur. Furthermore, there is some evidence that international environmental agreements work more as a self-selection device, collecting countries with lower emissions, instead of leading to lower emissions in themselves (Murdoch and Sandler 1997; Murdoch et al. 1997; Congleton 2001). Hence, there is a good reason for assuming that countries behave non-cooperatively when setting their emission level, even if they agree on emissions trading. Therefore, a non-cooperative model may very well be better at capturing the outcome of negotiations on an IEA than a cooperative model.

In the model, there are N countries that all emit a pollutant which mixes completely over the countries. Welfare of the countries is a function of damage from emissions and the costs from emissions. Specifically, let e_i be the emissions of the pollutant from country i. Damage is a function of all emissions, i.e., $D_i = D_i(E)$, with $E = \sum_{i=1}^{N} e_i$. It is assumed that damages are increasing in emissions, i.e., $D_i' > 0$ and $D'' \geq 0$. Costs of emissions are a function of own emissions only and are given by $C_i = C_i(e_i)$, with $C_i' < 0$ and $C_i'' \geq 0$.

2.2.1 No Emissions Trading

When emissions trading is not possible, country i's emissions e_i^{nt} are equal to its emission ceiling $\bar{e}_i^{nt}$. Here, the superscript nt denotes the no trading case. We assume that countries set the ceiling on their emissions non-cooperatively. The objective of the country then is

$$\max_{e_i^{nt}} W_i = -D_i(E^{nt}) - C_i(e_i^{nt})$$

The first order condition is:

$$\frac{\partial W^i}{\partial e_i^{nt}} = -D_i' - C_i' = 0 \tag{2.1}$$

This shows that countries choose their emission levels such that the marginal domestic costs of abatement equals the marginal damage of emissions. It follows from the first order condition that higher marginal damage will result in a lower emission ceiling. Conversely, higher marginal abatement cost leads to a higher emission ceiling.

Since (2.1) is a function of both e_i^{nt} and E_{-i}^{nt}, with $E_{-i}^{nt} = \sum_{j=1, j\neq i}^{N} e_j^{nt}$, a reaction function can be derived from it. Although it is not possible to give an expression for the reaction function itself, one can derive the slope of the reaction function through implicit differentiation of (2.1):

$$\frac{\partial e_i^{nt}}{\partial E_{-i}^{nt}} = -\frac{D''}{D'' + C''}, \quad -1 < \frac{\partial e_i^{nt}}{\partial E_{-i}^{nt}} < 0 \tag{2.2}$$

This shows that as foreign emissions increase, the country reacts by reducing its own emissions, although by less than the initial increase.

2.2.2 Countries are Price Takers

When countries agree on trading emissions amongst themselves, the analysis changes on several points. First of all, a price of permits, different from the marginal costs of abatement of the countries in the case without trading, will arise. This will affect all countries' willingness to abate. Furthermore, the welfare of the countries is now not only determined by the damage and costs of emissions, but also by the benefits of emissions trading.

In this section, we analyze the case where countries trade emissions, but have no influence on the price of permits. With the countries acting as price takers, the decision to buy or sell emissions is dependent on the price P of emissions. In the following, let the superscript pc denote the trading case where countries are price takers.

Country i's objective function now becomes:

$$\max_{e_i^{pc}, \bar{e}_i{}^{pc}} \quad W_i = -D_i(\bar{E}^{pc}) - C_i(e_i^{pc}) - P(e_i^{pc} - \bar{e}_i^{pc}) \tag{2.3}$$

Here, $\bar{E}^{pc} = \sum_{i=1}^{N} \bar{e}_i^{pc}$. There are two variables to be set: the emission ceiling of the country, and the actual emissions. The first order conditions are:

$$\frac{\partial W_i}{\partial e_i^{pc}} = -C_i' - P = 0 \tag{2.4}$$

$$\frac{\partial W_i}{\partial \bar{e}_i^{pc}} = -D_i' + P = 0 \tag{2.5}$$

Equation (2.4) says that country i will reduce its actual emissions to a level where the marginal costs of abatement are equal to the price of emission permits. Equation (2.5) shows that when countries are price takers, they want to set their emission ceilings such that the marginal damage from their own emissions is equal to the price of emission permits.

Since all countries that issue permits must have marginal damage equal to the permit price, there is only a competitive equilibrium in special circumstances. First we derive:

Proposition 1 *When countries differ in marginal damage from emissions,* *and they take the permit price as given, only the country with the lowest marginal damage will issue and sell permits.*

Proof First we show that there can only be one country issuing permits. Let there be $m \geq 2$ countries issuing permits to a total of E^*. Call two of these countries L and H with $D'_L(E^*) < D'_H(E^*)$. Then (2.5) cannot be satisfied simultaneously for both $i = L, H$.

Finally we show that is when there is one supplier, it has to be country 1 which is the country with the lowest D'_i. Suppose country $j \neq 1$ is the sole supplier with $\partial W_j/\partial \bar{e}^{pc}_j = 0$. Then $\partial W_1/\partial \bar{e}^{pc}_1 > 0$, so that country 1 sets $\bar{e}^{pc}_1 > 0$. However, when country 1 is the sole supplier, all other countries $j, j \neq 1$, have $\partial W_j/\partial \bar{e}^{pc}_j < 0$, so that they don't issue any permits.$\Box$

Note that this result is in sharp contrast to the one reached by Eyckmans and Proost (1996). In their model countries are also price takers. They assume that with trading, every country i receives de facto emission permits for E^0_i, where $C'_i(E^0_i) = 0$. When country j buys a unit of emission reduction from country i, country i reduces its emissions (from E^0_i) by one unit, and country j pays P to country i. In equilibrium, only the country with the highest marginal damage will buy emission reductions. The other countries free ride on the highest-damage country. So in Eyckmans and Proost (1996) countries do not alter their emission ceiling when emissions trading becomes possible. This is the main reason why their result differs from ours.

When there is only one country issuing permits, this country should realize that it has market power. Thus, price taking behavior cannot occur when countries differ in marginal damage. The other extreme would be the case where all countries have the same marginal damage function. In that case, equation (2.1) shows that all countries would already have the same marginal abatement cost without trade. Making the permits tradable will not change their emission level.

A more interesting situation arises when there are a number of countries (enough for them to be price takers) with the same lowest marginal damage cost function. For the remainder of this section, we assume:

Condition 1 *$D'_i \in \{D'_L, D'_H\}$ with $D'_L < D'_H$ and there are enough countries L and H to prevent market power.*

Now we can derive:

Proposition 2 *Under Condition 1, when there is perfect competition in the permit market, only countries L issue permits. They will issue $\bar{E}^{pc} > \bar{E}^{nt} > \sum_L e^{pc}_{L_i}$ permits. Individual $\bar{e}^{pc}_{L_i}$ are not determined and $e^{pc}_{L_i} < e^{nt}_{L_i}$. There will be at least one country H with $e^{pc}_{H_i} > e^{nt}_{H_i}$.*

Proof: For all countries L, condition (2.5) is the same, so that only the total $\bar{E}^{pc}$ is determined but the individual $\bar{e}^{pc}_{L_i}$ are not. Given that (2.5) is satisfied for $i \in L$, $\partial W_j / \partial \bar{e}^{pc}_j < 0$ for all $j \in H$ by Condition 1.

Furthermore, it follows from Proposition 1 and equations (2.4) and (2.5) that with perfect competition

$$D'_L\left(\bar{E}^{pc}\right) = -C'_{L_i}\left(e^{pc}_{L_i}\right) \tag{2.6}$$

$$D'_H\left(\bar{E}^{pc}\right) > -C'_{H_i}\left(e^{pc}_{H_i}\right) \tag{2.7}$$

Suppose that $\bar{E}^{pc} < \bar{E}^{nt}$. From (2.1) and (2.6) it then follows that $D'_L\left(\bar{E}^{pc}\right) < D'_L\left(\bar{E}^{nt}\right)$ and $-C'_{L_i}\left(e^{pc}_{L_i}\right) < -C'_{L_i}\left(e^{nt}_{L_i}\right)$. Furthermore, it holds that $D'_H\left(\bar{E}^{pc}\right) < D'_H\left(\bar{E}^{nt}\right)$ and $-C'_{H_i}\left(e^{pc}_{H_i}\right) < -C'_{H_i}\left(e^{nt}_{H_i}\right)$ since from (2.1) and (2.7), $-C'_{H_i}\left(e^{pc}_{H_i}\right) < D'_H\left(\bar{E}^{pc}\right) < D'_H\left(\bar{E}^{nt}\right) = -C'_{H_i}\left(e^{nt}_{H_i}\right)$. But we then find $-C'_i\left(e^{pc}_i\right) < -C'_i\left(e^{nt}_i\right) \quad \forall \quad i \in N$ which implies $E^{pc} < E^{nt}$. However, we assumed that $\bar{E}^{pc} = E^{pc} < \bar{E}^{nt} = E^{nt}$, so this is not possible. For $\bar{E}^{pc} = \bar{E}^{nt}$ we find, using the same line of reasoning that $-C'_{L_i}\left(e^{pc}_{L_i}\right) = -C'_{L_i}\left(e^{nt}_{L_i}\right)$ and $-C'_{H_i}\left(e^{pc}_{H_i}\right) < -C'_{H_i}\left(e^{nt}_{H_i}\right)$. This again implies $E^{pc} < E^{nt}$ which cannot hold.

Hence, the only possibility is $\bar{E}^{pc} > \bar{E}^{nt}$. In that case, $-C'_{L_i}\left(e^{pc}_{L_i}\right) > -C'_{L_i}\left(e^{nt}_{L_i}\right)$ from (2.1) and (2.6) which implies $e^{pc}_{L_i} < e^{nt}_{L_i}$. $\bar{E}^{pc} > \bar{E}^{nt}$ together with $e^{pc}_{L_i} < e^{nt}_{L_i}$ implies that $\sum_H e^{pc}_{H_i} > \sum_H e^{nt}_{H_i}$, so that $e^{pc}_{H_i} > e^{nt}_{H_i}$ for at least one country H.$\square$

This shows that when all countries are price takers, emissions with trading are higher than without. The reason for this is that with permit trading, only the countries with the lowest marginal damage issue permits. These countries are less concerned about the environmental damage from issuing permits, and therefore issue more permits than the buying countries H would issue without trade. It follows that the amount of permits issued by the seller countries is higher than their emission ceiling without emissions trading. So in this case, all sellers have hot air.

The rationale for the choices of the buyers and sellers is as follows. Suppose that the L-type countries expect that the H-type countries will set $\bar{e}_{H_i} = 0$. Then, the optimal strategy for the L-type countries is to set $\bar{e}_{L_i}$ such that $D'_{L_i} = P$. P, the market price of permits reflects both the marginal costs of abatement, according to equation (2.4), and the marginal benefit of increasing the ceiling, according to (2.5). Since permits are traded freely on the market, the H-type countries now can cover all their emissions by buying permits in the market. However, at the same time $D'_{H_i} > P$, so the marginal net benefit of issuing permits is negative for the buyers. Therefore, they will not issue any of them.

The next issue is the effect of a shift to emissions trading on welfare of the countries involved. The change in welfare from a shift to emissions trading is given by

$$\Delta W_i = D_i\left(\bar{E}^{nt}\right) - D_i\left(\bar{E}^{pc}\right) + C_i\left(e_i^{nt}\right) - C_i\left(e_i^{pc}\right) - P\left(e_i^{pc} - \bar{e}_i^{pc}\right)$$

This allows us to state the following

Proposition 3 *Countries L gain from trading only if they sell enough permits. Countries H gain only if the reduction in abatement costs from trading is large enough.*

Proof: From Proposition 2 we know that $\bar{E}^{pc} > \bar{E}^{nt}$, hence $D_i\left(\bar{E}^{nt}\right) - D_i\left(\bar{E}^{pc}\right) < 0$ for all countries. Countries L have $e_{L_i}^{pc} < e_{L_i}^{nt}$ so that $C_i\left(e_i^{nt}\right) - C_i\left(e_i^{pc}\right) < 0$. Hence, for a country L, $\Delta W_i > 0$ if $\bar{e}_i^{pc} - e_i^{pc}$ is positive and large enough. For a country H, $e_{H_i}^{pc} > e_{H_i}^{nt}$ so that $C_i\left(e_i^{nt}\right) - C_i\left(e_i^{pc}\right) > 0$.

Furthermore, $\bar{e}^{pc}_{H_i} = 0$ so that $P\left(e^{pc}_i - \bar{e}^{pc}_i\right) = Pe^{pc}_i > 0$. Then, for a country L, $\Delta W_i > 0$ when $C_i\left(e^{nt}_i\right) - C_i\left(e^{pc}_i\right)$ is large enough. $\square$

It is clear from Proposition 3 that countries may lose from the shift to emissions trading. The major problem is that total emissions always increase under perfect competition. To gain from the shift to emissions trading it is necessary that the sellers make a large enough profit on the sales of permits, while buyers should experience a large enough decrease in abatement costs.

2.2.3 Market Power

In this section, it is assumed that countries have market power. However, they only have an influence on the price of permits through the level of the emission ceiling they set, and not through the actual emission level. This would be the case if there is perfect competition in the permit market, which would arise if countries allow private entities to trade, instead of trading directly between governments.

The above implies that the price of permits is a function of the aggregate emission ceiling, i.e. $P = P(\bar{E}^t)$, $\bar{E}^t \equiv \sum_{i=1}^{N} \bar{e}^t_i$, where the superscript t stands for the case of trading with market power.

To determine the equilibrium price of emission permits, we will model the interaction between the countries as a Cournot-Nash model. The model has two stages. In stage one, countries determine their emission ceiling, while in the second stage actual trading takes place. As is usual with stage games, we will analyze the game backward, starting with stage two.

In the second stage, countries have set their emission ceiling $\bar{e}^t_i$ and now have to decide how much to trade. Each country chooses emissions so as to

$$\min_{e^t_i} \quad C_i(e^t_i) + P(e^t_i - \bar{e}^t_i)$$

The first order condition is

$$-C'_i = P \tag{2.8}$$

Hence, abatement costs are equalized between countries. Furthermore, the emission market must be in equilibrium

$$\sum_{i=1}^{N} e_i^t = \sum_{i=1}^{N} \bar{e}_i^t \tag{2.9}$$

Differentiating (2.8) and (2.9) with respect to $\bar{E}$ gives

$$P'(\bar{E}^t) = -C_i'' \frac{\partial\, e_i^t}{\partial\, \bar{E}^t} \quad \text{and} \quad \sum_{i=1}^{N} \frac{\partial\, e_i^t}{\partial\, \bar{E}^t} = 1 \quad \forall\, i = 1, \cdots, N$$

From this, it follows that[1]

$$\frac{\partial\, e_j^t}{\partial\, \bar{E}^t} \sum_{i=1}^{N} \left(\frac{C_j''}{C_i''} \right) = 1$$

Combining and rearranging gives

$$P'(\bar{E}^t) = -C_j'' \frac{\partial\, e_j^t}{\partial\, \bar{E}^t} = -\frac{1}{\sum_{i=1}^{N} \left(\frac{1}{C_i''} \right)} < 0 \tag{2.10}$$

Furthermore

$$\frac{\partial\, e_i^t}{\partial\, \bar{E}^t} = \frac{1}{\sum_{j=1}^{N} \left(\frac{C_i''}{C_j''} \right)} \in (0, 1)$$

We now turn to stage two of the game where all countries determine their emission ceiling. The objective of country i is to

$$\max_{\bar{e}_i}\ W_i = -D_i(\bar{E}^t) - C_i(e_i^t(\bar{E}^t)) - P(\bar{E}^t)(e_i^t(\bar{E}^t) - \bar{e}_i^t) \tag{2.11}$$

The first order condition is

$$\frac{\partial W^i}{\partial \bar{e}_i^t} = -D_i' - P'(e_i^t - \bar{e}_i^t) + P = 0 \tag{2.12}$$

[1] This follows from:

$$C_i'' \frac{\partial\, e_i^t}{\partial\, \bar{E}^t} = C_j'' \frac{\partial\, e_j^t}{\partial\, \bar{E}^t} \quad \Rightarrow \quad \frac{\partial\, e_i^t}{\partial\, \bar{E}^t} = \frac{C_j''}{C_i''} \frac{\partial\, e_j^t}{\partial\, \bar{E}^t}$$

Summation of both sides over N gives the required result.

The second order condition for welfare maximization is

$$\frac{\partial^2 W^i}{\partial (\bar{e}_i^t)^2} = -D_i'' - P''(e_i^t - \bar{e}_i^t) - P'\left(\frac{\partial\, e_i^t}{\partial\, \bar{E}^t} - 2\right) < 0 \tag{2.13}$$

The first and third term are positive and therefore pointing in the right direction. However, the sign of the second term depends on the sign of P'' and on whether the country is a seller or buyer. Hence, it is uncertain whether the second order condition always holds. It will hold when the term $P''(e_i - \bar{e}_i)$ is small enough, which is assumed in the remainder of this chapter.

Rewriting equation (2.12) using (2.8) gives

$$D_i' + P'(e_i^t - \bar{e}_i^t) = -C_i' \tag{2.14}$$

This equation explicitly contains $\bar{e}_i$, therefore, we can derive

$$\bar{e}_i^t = \frac{D_i' + C_i'}{P'} + e_i^t$$

This equation gives the relation between the emission ceiling of a country and its actual emissions.

The relation between the emissions ceiling of one country to those of the other countries can be expressed in a reaction function. The slope of this function is found by implicit differentiation of equation (2.12):

$$\frac{\partial \bar{e}_i^t}{\partial \bar{E}_{-i}^t} = -\frac{W_{\bar{e}_i \bar{E}_{-i}}^i}{W_{\bar{e}_i \bar{e}_i}^i} = -\frac{D_i'' + P''(e_i^t - \bar{e}_i^t) + P'\left(\frac{\partial\, e_i^t}{\partial\, \bar{E}^t} - 1\right)}{D_i'' + P''(e_i^t - \bar{e}_i^t) + P'\left(\frac{\partial\, e_i^t}{\partial\, \bar{E}^t} - 2\right)} \tag{2.15}$$

From the second order condition (2.13), the denominator of (2.15) is positive. For the equilibrium to be stable, we need the nominator to be positive as well. This is assumed to be the case, and hence we find that $-1 < \partial \bar{e}_i / \partial \bar{E}_{-i} < 0$.

In the remainder of this section, we examine how the possibility of international emissions trading changes the abatement commitments of the countries. Furthermore, the effects on total emissions, and welfare will be examined.

Abatement Commitments

We saw before that when countries are price takers, a seller will set a higher and a buyer a lower emission ceiling with trading than without. With market power, this may change. Now the countries will try to affect the price of permits in a direction advantageous to them. The result is as follows.

Using the Mean Value Theorem (see Sydsæter and Hammond 1995, p. 222), define $\bar{C}_i''$ by:

$$\bar{C}_i'' \equiv \frac{C_i'(e_i^t) - C_i'(e_i^{nt})}{e_i^t - e_i^{nt}} \tag{2.16}$$

Then we have:

Proposition 4 *When countries have market power:*

1. The higher D_i', the higher $e_i^t - \bar{e}_i^t$ for the countries i that set $\bar{e}_i^t > 0$. There may be countries that set $\bar{e}_i^t = 0$. These will be the countries with the highest D_i'.

2. For the countries i that set $\bar{e}_i^t > 0$, a permit seller will set $\bar{e}_i^t \gtreqless \bar{e}_i^{nt}$ and a buyer will set $\bar{e}_i^t \lesseqgtr e_i^{nt}$ if:

$$\sum_{j=1}^{N} \frac{\bar{C}_i''}{C_j''(e_i^t)} \gtreqless 1 + \frac{D_i'(\bar{E}^t) - D_i'(\bar{E}^{nt})}{P'(e_i^t - \bar{e}_i^t)} \tag{2.17}$$

where $\bar{C}_i''$ is defined by (2.16).

Proof 1. Equation (2.12) must hold for all countries i with $\bar{e}_i^t > 0$. Differentiating with respect to D_i' yields:

$$\frac{d(e_i^t - \bar{e}_i^t)}{dD_i'} = \frac{1}{P'} > 0$$

From (2.12), countries with the highest D'_j may find that at $\bar{e}_j^t = 0$:

$$\frac{\partial W^j}{\partial \bar{e}_j^t} = -D'_j - P' e_j^t + P < 0 \tag{2.18}$$

In that case, these countries will set $\bar{e}_j^t = 0$.

2. From (2.16), we have:

$$\bar{e}_i^t - e_i^{nt} = \bar{e}_i^t - e_i^t + \frac{C'_i(e_i^t) - C'_i(e_i^{nt})}{\bar{C}''_i}$$

Thus:

$$\bar{e}_i^t \gtreqless \bar{e}_i^{nt} \Leftrightarrow \left[\bar{C}''_i + \frac{C'_i(e_i^t) - C'_i(e_i^{nt})}{\bar{e}_i^t - e_i^t}\right] \frac{\bar{e}_i^t - e_i^t}{\bar{C}''_i} \gtreqless 0$$

For sellers (with $\bar{e}_i^t > e_i^t$), $\bar{e}_i^t \gtreqless \bar{e}_i^{nt}$ and for buyers (with $\bar{e}_i^t < e_i^t$), $\bar{e}_i^t \lesseqgtr \bar{e}_i^{nt}$ when:

$$\bar{C}''_i + \frac{C'_i(e_i^t) - C'_i(e_i^{nt})}{\bar{e}_i^t - e_i^t} \gtreqless 0$$

Substituting (2.1) and (2.14), this becomes:

$$\bar{C}''_i \gtreqless \frac{D'_i(\bar{E}^t) + P'(e_i^t - \bar{e}_i^t) - D'_i(\bar{E}^{nt})}{\bar{e}_i^t - e_i^t}$$

Dividing both sides by $-P'$ and substituting (2.10) gives (2.17). □

For an intuitive explanation, we examine the LHS and RHS of (2.17) in turn. First look at the LHS of (2.17). As can be seen from (2.10), this is equal to $\bar{C}''_i / - P'$. If $-P'$ is large, a small change in the total amount of permits will have a large effect on the price of permits. Hence, in this case, countries have a strong incentive to affect the price in the direction advantageous to them. If $\bar{C}''_i$ is large, a small change in emissions has a large effect on marginal abatement costs. Now, suppose that a seller has a combination of a low $\bar{C}''_i$ and high $-P'$. Then it takes only a small decrease in permits to achieve a large increase in permit price. At the same time, given the change in the permit price, the country will lower its own emissions by a large amount. This makes it possible for the country to sell more permits at a rather low extra marginal abatement costs for itself. For a buyer, the reverse happens. Lowering the price of permits implies that the country will buy more permits. When $\bar{C}_i''$ is low, the country's emissions will increase much and hence the country can lower costs of abatement by issuing more permits.

Now turn to the RHS of (2.17). For a seller, the term $P'(e_i^t - \bar{e}_i^t)$ is positive, while for a buyer it is negative. Hence, for a seller, the RHS of (2.17) is relatively large when $\bar{E}^t > \bar{E}^{nt}$, while for a buyer, the RHS is large when $\bar{E}^t < \bar{E}^{nt}$. So, when the RHS is large for a seller, marginal damage from emissions is high. It then pays for the country to lower total emissions by lowering its emissions ceiling. Conversely, a buyer will want a higher ceiling when the RHS is relatively large.

What happens in the end depends on the relative size of the effects. So, if for a seller, marginal abatement costs change little with a change in emissions ($\bar{C}_i''$ is low) while it has strong market power ($-P'$ is large), and at the same time total emissions under trading are larger than they were under the no trading regime, the country has a strong incentive to limit the number of permits. This is both because it can increase its gain from trading, and because it can lower its damage from emissions by doing so.

Note that also with market power, it is very well possible that seller countries set $\bar{e}_i^t > \bar{e}_i^{nt}$, which means that they receive hot air. This will happen when marginal emission costs increase much when shifting to trading and the price function is rather flat ($\bar{C}_i''/-P'$ is large) and when trading does not lead to much lower total emissions.

In an interior solution, all countries set a positive emission ceiling. However, an interior solution is not always possible. This will be the case when for at least one country, the net benefits of lowering total emissions are positive, but its own emission ceiling is zero already. Hence, in that case, the country cannot lower total emissions any further by lowering its own emission ceiling. This then gives the boundary solution where at least one country sets its emission ceiling equal to zero.

Aggregate Emissions

The next issue to address is the influence of trade on total emissions. We have seen above that both potential sellers and buyers will alter their emission ceilings. Only by chance will these changes cancel each other out, leaving total emissions unchanged. It is far more likely that total emissions will change as a result of emissions trading.

Recall that we have defined the damage in all countries to be a strictly increasing function of aggregate emissions which is at least twice differentiable. Hence, marginal damage is also a strictly increasing function of aggregate emissions. Since aggregate emissions are equal for all countries, we know that total damage and marginal damage move in the same direction for all countries when aggregate emissions change. Then, when we aggregate the marginal damage of all countries, the same relation exists; when aggregate emissions increase, aggregate marginal damage increases, and vice versa. Therefore, to examine the difference in aggregate emissions, we can compare the level of aggregate marginal damage both with and without emissions trading.

First we look at the case where all countries issue permits. Then (2.12) holds for all countries i, $i = 1, ..., N$. From equations (2.1) and (2.12), trade increases aggregate emissions if and only if:

$$\sum_{i=1}^{N} D_i'(\bar{E}^t) - \sum_{i=1}^{N} D_i'(\bar{E}^{nt}) = \sum_{i=1}^{N} [P - P'(e_i^t - \bar{e}_i^t)] + \sum_{i=1}^{N} C_i'\left(e_i^{nt}\right) > 0$$

This equation can be simplified by noting that $\sum_{i=1}^{N}(e_i^t - \bar{e}_i^t) = 0$, i.e. the permit market is in equilibrium. This means that emissions increase with trade if and only if:

$$P + \frac{\sum_{i=1}^{N} C_i'\left(e_i^{nt}\right)}{N} > 0$$

Thus we have:

Proposition 5 *Total emissions may be higher under an emissions trading scheme than in the noncooperative equilibrium without trading. Specifically,* *in the interior solution where all countries issue permits:*

$$\bar{E}^t \gtreqless \bar{E}^{nt} \Leftrightarrow P^t \gtreqless \frac{-\sum_{i=1}^{N} C_i'\left(e_i^{nt}\right)}{N}$$

Hence, only when the price of emissions is equal to the average of the marginal costs of abatement without trade of the countries, the move to trade will not change total emissions. If the price of permits is lower (higher) than the average marginal costs without trading, total emissions will be lower (higher) with trade than without trade. The rationale for this is that if the price of permits is lower than the average marginal costs without trade, the average marginal benefits of issuing permits[2] decrease and countries will on average issue less permits. The reverse holds for a higher price of permits than the average of the marginal costs without trade.

The above holds for the interior solution where all countries issue permits. There can also be a boundary solution where one or more countries do not issue permits. When there are countries j that don't issue any permits, we can define a λ_j for these countries:

$$\lambda_j \equiv -D_j'(\bar{E}^t) - P'(\bar{E}^t)e_j^t + P(\bar{E}^t) < 0$$

The inequality follows from (2.18). Here λ_j is the shadow value of an additional permit, which is negative for the country that sets $\bar{e}_j^t = 0$ because it would prefer a lower total permit level.

In this case we find that

$$\bar{E}^t \gtreqless \bar{E}^{nt} \Leftrightarrow P^t - \frac{\sum_j \lambda_j}{N} \gtreqless \frac{-\sum_{i=1}^{N} C_i'\left(e_i^{nt}\right)}{N} \tag{2.19}$$

Hence, in the boundary solution, we find that total emissions may be higher with trading than without, even when the permit price is lower than the average marginal abatement costs in the case without trading. This is because the countries that don't issue any permits cannot reduce the number

[2]The benefits of issuing more permits are either that a country can reduce its own abatement, or sell more or buy less permits.

of permits they issue any further.

The above shows that international emissions trading can lead to both lower and higher total emissions.

Welfare

There are two effects from emissions trading on welfare. First of all, emissions trading will alter the costs of abatement for the trading countries. For the buyers of permits, the costs of abatement will be lower with trading. For the sellers, the costs will be higher, but they will be compensated through the price they receive for the permits. It is clear that all countries will be winners in this respect. The second effect is that trading alters the incentives for countries to emit and thereby alters the aggregate emission level. If total emissions decrease because of the possibility of emissions trading, then benefits, and thereby welfare, in all countries will rise. However, if emissions trading leads to higher overall emissions levels, this decreases welfare of all countries involved in the problem.

Define e_i^{ot} as the emissions of country i when it does not participate in the emissions trading scheme while all other countries continue to emit $\bar{E}_{-i}^t$ as if country i were participating. Thus e_i^{ot} is the e_i that maximizes

$$W_i = -D_i\left(e_i + \bar{E}_{-i}^t\right) - C_i\left(e_i\right)$$

Furthermore, let $E^{io} \equiv \bar{E}_{-i}^t + e_i^{ot}$ be the total emission level when all other countries participate in the emissions trading scheme, but i does not trade. The total effect on welfare from a shift to emissions trading can then be expressed as:

$$\begin{aligned} \Delta W_i = \; & \left[D_i^{nt} - D_i(E^{io}) + C_i^{nt} - C_i(e_i^{ot})\right] \\ & + \left[D_i(E^{io}) - D_i^t + C_i(e_i^{ot}) - C_i^t - P(e_i^t - \bar{e}_i^t)\right] \end{aligned} \tag{2.20}$$

where Δ represents a discrete change. The first term between square brackets in (2.20) denotes the change in welfare from the shift by all other countries to emissions trading, with country i staying outside the trading scheme.

The second term between square brackets denotes country i's welfare gain from joining the international emissions trading scheme when all other countries are already participating in it. Thus a country gains from emissions trading when the first term is postive and when it is negative, but not too large.

Proposition 6 *When total emissions are lower with emissions trading than without emissions trading, all countries gain from emissions trading. However, when $\bar{E}^t > \bar{E}^{nt}$, there may be countries that lose from emissions trading.*

Proof The first term in square brackets in (2.20) negative (positive) if $E^{io} > E^{nt}$ ($E^{io} > E^{nt}$). This is because $-1 < d\, e_i^{ot}/d\, \bar{E}_{-i} < 0$ by (2.2) and the term $\left[D_i^{nt} - D_i(E^{io}) + C_i^{nt} - C_i(e_i^{ot})\right]$ is negative (positive) if $\bar{E}_{-i}^{io} > \bar{E}_{-i}^{nt}$ ($\bar{E}_{-i}^{io} > \bar{E}_{-i}^{nt}$). This is because:

$$\frac{dW_i^{ot}(e_i^{ot}, \bar{E}_{-i})}{d\bar{E}_{-i}} = \frac{\partial\, W_i^{ot}}{\partial\, \bar{E}_{-i}} + \frac{\partial\, W_i^{ot}}{\partial\, e_i^{ot}} \frac{de_i^{ot}}{d\bar{E}_{-i}} < 0$$

To see this, rewrite the expression as

$$\frac{dW_i^{ot}(e_i^{ot}, \bar{E}_{-i})}{d\bar{E}_{-i}} = -\frac{\partial\, D_i^{ot}}{\partial\, \bar{E}} \left(1 + \frac{de_i^{ot}}{d\bar{E}_{-i}}\right) - \frac{\partial\, C_i^{ot}}{\partial\, e_i^{ot}} \frac{de_i^{ot}}{d\bar{E}_{-i}} < 0$$

We know that $D_i' > 0$ and that $-1 < d\, e_i^{ot}/d\, \bar{E}_{-i} < 0$ by (2.2), so that the first term is positive. Furthermore, $C_i' < 0$, so that the second term is positive as well.

The second term in brackets in (2.20) is nonnegative, and positive when $\bar{e}_i^t \neq e_i^{ot}$. If, when allowed to trade, country i decides to issue e_i^{ot} permits and not to trade, then there is no welfare change. However, if the country sets $\bar{e}_i^t \neq e_i^{ot}$ and trades, then welfare increases.

Thus when $\bar{E}^t \leq \bar{E}^{nt}$, then $W_i^t \geq W_i^{nt}$ for all countries i. However, when $\bar{E}^t > \bar{E}^{nt}$, there may be countries that lose from emissions trading. □

The rationale for this result is straightforward. As long as other countries keep their emission levels constant, a country always gains from trading. However, emissions trading may alter the total emission level. When total emissions decrease as a result from trading, damage in all countries decreases. So in this case countries gain from trading and from lower overall emissions. However, when trading leads to an increase in emissions, damage increases. If the increase in damage is large enough, it may outdo the individual gain from trading.

Note that this result is different than the one found by Helm (2003). Helm finds that even when total emissions decrease as a result from trading, some countries may experience a decrease in welfare. The problem is that Helm only analyzes several scenarios, without showing that these scenarios can actually arise.

2.3 A Cooperative Model

In the previous section, we used a non-cooperative model to analyze the effect of a shift to emissions trading. Alternatively, a cooperative model can be used. In this section we analyze a model where countries cooperate on emission reduction, but do not accept the use of direct side payments. Both the case where emissions trading is not allowed and where it is allowed is analyzed. The cooperative solution used here is the Nash bargaining solution.[3]

2.3.1 No international emissions trading

If the countries decide not to allow international emissions trading, the Nash bargaining solution is the $(\bar{e}_1^{cn}, \bar{e}_2^{cn}, \cdots, \bar{e}_n^{cn})$ combination that solves

$$\max_{\bar{e}_i} J = \sum_{i}^{N} log[-D_i(\bar{E}^{cn}) - C_i(\bar{e}_i^{cn}) - A_i]$$

Here, $(A_1, A_2, \cdots, A_n)$ is the threat point and superscript cn denotes the cooperative case without trading. The threat point gives the net benefits for

[3]For an explanation of the Nash bargaining solution see Friedman (1991) and Muthoo (1999). An application in environmental economics is given by Hoel (1991).

both countries if no agreement is reached. It is assumed that in the absence of an agreement, the outcome is the non-cooperative equilibrium without international trading. The first order condition of the Nash bargaining solution for country i's emissions is

$$\frac{\partial J}{\partial \bar{e}_i^{cn}} = \frac{-D_i' - C_i'}{-D_i - C_i - A_i} + \sum_{j,j\neq i}^{N} \frac{-D_j'}{-D_j - C_j - A_j} = 0 \qquad (2.21)$$

In the following we will replace $-D_i(\bar{E}) - C_i(\bar{e}_i^{cn})$ by W_i. Rewriting equation (2.21) gives:

$$\sum_{j=1}^{N} \alpha_j D_j' = -\alpha_i C_i' \qquad \text{where} \qquad \alpha_i \equiv \frac{1}{W_i - A_i} \qquad (2.22)$$

Since $\alpha_i \geq 0$, equation (2.22) implies that in the Nash bargaining solution countries take the foreign damage inflicted by domestic pollution into account, although disproportionately so since a country either weighs its own damage higher than the foreign country's, or it weighs the other country's damage higher. From this it follows that aggregate emissions will be less under the Nash bargaining solution without trade than in the non-cooperative equilibrium without trade.

Proposition 7 *Assume that $C_i(e^*) = C_j(e^*)$ for all $e^* \geq 0$ and all $i, j \in N$, then the higher a country's marginal damage, the more it gains from cooperation.*

Proof: Suppose there are two countries $h, l \in N$ with $D_h' > D_l'$. Then, for any $\bar{E} < \bar{E}^{nt}$, $D_h(\bar{E}^{nt}) - D_h(\bar{E}) > D_l(\bar{E}^{nt}) - D_l(\bar{E})$. From (2.22), it follows that

$$\sum_{j}^{N} \alpha_j D_j' = -\alpha_h C_h' = -\alpha_l C_l' \qquad (2.23)$$

Suppose that $\bar{e}_h^{cn} \geq \bar{e}_l^{cn}$, then $-C_h'(e_h^{cn}) \leq -C_l'(e_l^{cn})$. But since we also have that $-C_h'(e_h^{nt}) > -C_l'(e_l^{nt})$ it follows that $W_h^{cn} - A_h > W_l^{cn} - A_l$ and hence that $\alpha_h < \alpha_l$. But then (2.23) cannot be satisfied. Hence, we must have that $\bar{e}_h^{cn} < \bar{e}_l^{cn}$, so that $-C_h'(e_h^{cn}) > -C_l'(e_l^{cn})$. Then, we need $\alpha_h < \alpha_l$ for (2.23) to hold. □

The reason that high-damage countries gain more from cooperation than low-damage countries is that cooperation leads to lower total emissions. For high-damage countries, the decrease in damage is higher for every decrease in total emissions.

As long as the gains from cooperation are unequal, it is not optimal to equate marginal abatement costs across countries. The high-damage countries pay for their higher gains with higher marginal abatement costs.

2.3.2 International Emissions Trading

With international emissions trading, the countries have to set both their emission limit and their actual emissions. Since countries behave cooperatively, no country will use its market power to increase its welfare. Therefore, there is no difference between the case with market power and the one where countries are price takers. A country takes the effect of a change in its own emission ceiling on all countries' trade in permits into account. The Nash bargaining solution is the $(e_1^{ct}, \bar{e}_1^{ct}, e_2^{ct}, \bar{e}_2^{ct}, \cdots, e_n^{ct}, \bar{e}_n^{ct})$ combination that solves

$$\max_{e_i^{ct}, \bar{e}_i^{ct}} J = \sum_{i=1}^{N} log\left[-D_i(\bar{E}^{ct}) - C_i(e_i^{ct}) - P(\bar{E}^{ct})\left(e_i^{ct} - \bar{e}_i^{ct}\right) - A_i\right] \tag{2.24}$$

It is assumed that when the countries do not reach an agreement on emission reduction, they will not allow emissions trading between them either. Hence, the threat point is the non-cooperative equilibrium without international emissions trading. In the following we will replace $-D_i(\bar{E}) - C_i(e_i) - P(e_i - \bar{e}_i)$ by W_i. The first order conditions of the Nash bargaining solution for country i are

$$\frac{\partial J}{\partial e_i^{ct}} = \frac{-C_i' - P}{W_i - A_i} = 0 \tag{2.25}$$

$$\frac{\partial J}{\partial \bar{e}_i^{ct}} = \frac{P}{W_i - A_i} + \sum_{j}^{N} \frac{-D_j' - P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)}{W_j - A_j} = 0 \tag{2.26}$$

with P' given, as before, by (2.10). Equation (2.25) is the usual condition that with trade, the country sets its marginal abatement costs equal to the price of permits. Rewriting equation (2.26) gives:

$$\sum_{j=1}^{N} \alpha_j \left[D_j' + P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)\right] = \alpha_i P \tag{2.27}$$

Proposition 8 *If there is an interior solution, with (2.27) holding for all countries, the full cooperative solution is realized with equal welfare gain for all countries. If there is no interior solution, a boundary solution will arise where at least one buyer country sets $\bar{e}_i^{ct} = 0 < \bar{e}_i^{cn}$. For the countries with $\bar{e}_i^{ct} = 0 < \bar{e}_i^{cn}$, (2.27) is replaced by*

$$\sum_{j=1}^{N} \alpha_j \left[D_j' + P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)\right] > \alpha_i P \tag{2.28}$$

In this case, the welfare gain for the countries with $\bar{e}_i^{ct} = 0$ is larger than for the other countries.

Proof For an interior solution, (2.27) has to hold for all countries. This can only be the case when $\alpha_i = \alpha_j \; \forall \, i, j \in N$, which implies $W_i - A_i = W_j - A_j \; \forall \, i, j \in N$. Substituting (2.25), equation (2.27) then becomes

$$\sum_{j=1}^{N} D_j'(\bar{E}^{ct}) = -C_i'(e_i^{ct}) \quad \forall \, i, j \in N$$

which is equal to the full cooperative solution.

In a boundary solution, $\partial J / \partial \bar{e}_i^{ct} < 0$ at $\bar{e}_i^{ct} = 0$ for at least one country i. From (2.26) and (2.27) it then follows that for these countries (2.28) must hold. Call the countries for which (2.28) [(2.27)] holds the (un)constrained countries c (u). From a comparison of (2.27) and (2.28) it is clear that $\alpha_c < \alpha_u$ for all $c, u \in N$. By (2.22), this means that $W_c - A_c > W_u - A_u$. $\square$

The full cooperative solution will only be realized when the transfer payments that are possible through emissions trading are large enough. However, we implicitly have assumed that $\bar{e} \geq 0$. This seems to be a realistic assumption in the sense that a country is not likely to announce a negative abatement goal. However, if we allow for $\bar{e} < 0$ it can easily be seen that an interior solution is always possible. This of course amounts to saying that when countries are willing to pay side payments, the full cooperative equilibrium is attainable.

We can divide the countries into two groups:

Definition 1 *Define:*

$$\theta_i \equiv P - \sum_{j=1, j\neq i}^{N} \frac{\alpha_j}{\alpha_i} \left[D'_j + P' \left(e_j^{ct} - \bar{e}_j^{ct} \right) \right] \tag{2.29}$$

Denote countries with $D'_i > \theta_i$ *by high-damage countries* $h_i \in H$, *and countries with* $D'_i < \theta_i$ *by low-damage countries* $l_i \in L$.

We can now state:

Proposition 9 *High-damage countries are permit buyers and low-damage countries are permit sellers.*

Proof Rewrite (2.27) as

$$D'_i + P' \left(e_i^{ct} - \bar{e}_i^{ct} \right) + \sum_{j=1, j\neq i}^{N} \frac{\alpha_j}{\alpha_i} \left[D'_j + P' \left(e_j^{ct} - \bar{e}_j^{ct} \right) \right] = P$$

Then for countries with $D'_i > \theta_i$, with θ_i defined by (2.29), it must hold that $e_i^{ct} > \bar{e}_i^{ct}$, while for countries with $D'_i < \theta_i$, it must hold that $e_i^{ct} < \bar{e}_i^{ct}$.

In the boundary solution, (2.28) holds for the constrained countries, while (2.27) holds for the unconstrained countries. Rewriting (2.28), using that $\bar{e}_i^{ct} = 0$ for these countries, gives

$$D'_i + P' e_i^{ct} + \sum_{j=1, j\neq i}^{N} \frac{\alpha_j}{\alpha_i} \left[D'_j + P' \left(e_j^{ct} - \bar{e}_j^{ct} \right) \right] > P$$

Then first of all, since $P'e_i^{ct} < 0$, it holds that $D_i' > \theta_i$ for these countries. Furthermore, the fact that $\bar{e}_i^{ct} = 0$ and $e_i > 0$ implies that these countries are buyers. □

Abatement Commitments

Using the Mean Value Theorem (see Sydsæter and Hammond 1995, p. 222), define:

$$\tilde{C}_i'' \equiv \frac{C_i'(e_i^{ct}) - C_i'(\bar{e}_i^{cn})}{e_i^{ct} - \bar{e}_i^{cn}} \tag{2.30}$$

Comparing the outcome without emissions trading with the one with emissions trading for an individual country then leads to the following result:

Proposition 10 *i) In the full cooperative solution, a permit seller will set $\bar{e}_i^{ct} \gtreqless \bar{e}_i^{cn}$ while a buyer will set $\bar{e}_i^{ct} \lesseqgtr \bar{e}_i^{cn}$ if*

$$\sum_{j=1}^{N} \frac{\tilde{C}_i''}{C_j''(e_j^{ct})} \gtreqless \frac{\sum_{j=1}^{N} D_j'(\bar{E}_j^{ct}) - \sum_{j=1}^{N} \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j'(\bar{E}_j^{cn})}{P'(e_i^{ct} - \bar{e}_i^{ct})} \tag{2.31}$$

ii) In the boundary solution at least one buyer country sets $\bar{e}_i^{ct} = 0 < \bar{e}_i^{cn}$. Furthermore, a permit seller will set $\bar{e}_i^{ct} \gtreqless \bar{e}_i^{cn}$ while a buyer with $\bar{e}_i^{ct} > 0$ will set $\bar{e}_i^{ct} \lesseqgtr \bar{e}_i^{cn}$ if

$$\sum_{j=1}^{N} \frac{\tilde{C}_i''}{C_j''(e_j^{ct})} \gtreqless \frac{\sum_{j=1}^{N} \frac{\alpha_j^{ct}}{\alpha_i^{ct}} \left[D_j'(\bar{E}_j^{ct}) + P'(e_j^{ct} - \bar{e}_j^{ct})\right] - \sum_{j=1}^{N} \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j'(\bar{E}_j^{cn})}{P'(e_i^{ct} - \bar{e}_i^{ct})} \tag{2.32}$$

Proof From (2.30), we have:

$$\bar{e}_i^{ct} - e_i^{cn} = \bar{e}_i^{ct} - e_i^{ct} + \frac{C_i'(e_i^{ct}) - C_i'(e_i^{cn})}{\tilde{C}_i''}$$

Thus:

$$\bar{e}_i^{ct} \gtreqless \bar{e}_i^{cn} \Leftrightarrow \left[\tilde{C}_i'' + \frac{C_i'(e_i^{ct}) - C_i'(e_i^{cn})}{\bar{e}_i^{ct} - e_i^{ct}}\right] \frac{\bar{e}_i^{ct} - e_i^{ct}}{\tilde{C}_i''} \gtreqless 0$$

For sellers (with $\bar{e}_i^{ct} > e_i^{ct}$), $\bar{e}_i^{ct} \gtreqless \bar{e}_i^{cn}$ and for buyers (with $\bar{e}_i^{ct} < e_i^{ct}$), $\bar{e}_i^{ct} \lesseqgtr \bar{e}_i^{cn}$ when:

$$\tilde{C}_i'' + \frac{C_i'(e_i^{ct}) - C_i'(e_i^{cn})}{\bar{e}_i^{ct} - e_i^{ct}} \gtreqless 0$$

Substituting (2.22), (2.25) and (2.27), this becomes:

$$\tilde{C}_i'' \gtreqless \frac{\sum_j \frac{\alpha_j^{ct}}{\alpha_i^{ct}} \left[D_j'(\bar{E}^{ct}) + P'(e_j^{ct} - \bar{e}_j^{ct})\right] - \sum_j \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j'(\bar{E}^{cn})}{\bar{e}_i^{ct} - e_i^{ct}}$$

Dividing both sides by $-P'$ and substituting (2.10) gives (2.32). For (2.31), substitute $\alpha_i = \alpha_j,\ i, j = 1, \cdots, N$ into (2.32).$\square$

In the interior solution, the solution found here is an example of the Split-The-Difference rule often found with the Nash bargaining solution (see Muthoo (1999) p. 15). Hence, in that case, the welfare gain is equal for all countries. What this means is that in the interior solution, emissions trading makes it possible for the high-damage countries to pay side payments to the low-damage countries, such that the full cooperative solution can be reached. However, it may happen that the side payments necessary to reach the full cooperative solution are too large to be implemented with emissions trading. In that case, we end up in a boundary solution. It is clear that in that case, the constrained countries gain more than the unconstrained countries, since the constrained countries would like to transfer more wealth to the other countries, but cannot do so.

The intuitive explanation of the individual emission ceilings is basically the same as the one found in the non-cooperative model with market power. However, in the current case, the countries take the effect of their emission ceiling on other countries in account. The result in this case is that also when countries play cooperatively, they may set a higher or lower emission ceiling, dependent on their cost structure and on the effect of emissions trading on total emissions.

Aggregate emissions

As before, we want to know whether emissions trading leads to higher or lower emissions. First, define:

$$\gamma_i \equiv P - D_i' - P'\left(\bar{E}^{ct}\right)\left(e_i^{ct} - \bar{e}_i^{ct}\right) - \sum_{j=1, j\neq i}^{N} \frac{\alpha_j}{\alpha_i}\left[D_j' + P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)\right] \quad (2.33)$$

Unconstrained countries with $\bar{e}_i^{ct} > 0$ have $\gamma_i = 0$ by (2.27), while constrained countries with $\bar{e}_i^{ct} = 0$ have $\gamma_i < 0$ by (2.28). γ_i is the shadow value of an additional permit, which is negative for a constrained country, because it would prefer less permits. We can then state

Proposition 11 *Total emissions may be higher or lower with emissions trading. Specifically,*

$$\bar{E}^{ct} \gtreqless \bar{E}^{cn} \quad \Leftrightarrow \quad P + \Omega - \frac{\sum_i \gamma_i}{N} \gtreqless \frac{-\sum_{i=1}^{N} C_i'\left(e_i^{cn}\right)}{N} \quad (2.34)$$

where

$$\Omega \equiv \left[\sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j'\left(\bar{E}^{cn}\right) - \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \frac{\alpha_j^{ct}}{\alpha_i^{ct}}\left[D_j'\left(\bar{E}^{ct}\right) + P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)\right]\right] \Big/ N$$

where Ω may be smaller or larger than zero.

Proof Rewrite (2.22) and (2.33) as

$$\begin{aligned} D_i'\left(\bar{E}^{cn}\right) + \sum_{j=1, j\neq i}^{N} \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j' &= -C_i' \\ D_i' + P'\left(e_i^{ct} - \bar{e}_i^{ct}\right) + \sum_{j=1, j\neq i}^{N} \frac{\alpha_j^{ct}}{\alpha_i^{ct}}\left[D_j' + P'\left(e_j^{ct} - \bar{e}_j^{ct}\right)\right] + \gamma_i &= P \end{aligned}$$

respectively. Summing over N, isolating $\sum_{i=1}^{N} D_i'$ in both cases and comparing gives (2.34). When there is an interior solution with emissions trading,

$\alpha_j^{ct}/\alpha_i^{ct} = 1$ and $\gamma_i = 0$ for all i. Furthermore,

$$\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} P' \left(e_j^{ct} - \bar{e}_j^{ct} \right) = 0$$

so that (2.34) becomes $\bar{E}^{ct} \gtreqless \bar{E}^{cn} \quad \Leftrightarrow$

$$P + \left[\sum_{i=1}^{N} \sum_{j=1, j \neq i}^{N} \frac{\alpha_j^{cn}}{\alpha_i^{cn}} D_j' \left(\bar{E}^{cn} \right) - (N-1) \sum_{i=1}^{N} D_j' \left(\bar{E}^{ct} \right) \right] / N \gtreqless \frac{-\sum_{i=1}^{N} C_i' \left(e_i^{cn} \right)}{N}$$

When $\bar{E}^{ct} \geq \bar{E}^{cn}$, $D_j' \left(\bar{E}^{ct} \right) \geq D_j' \left(\bar{E}^{cn} \right)$. However, $\sum \alpha_j / \alpha_i = N$ when $\alpha_j = \alpha_i$ and $\sum \alpha_j / \alpha_i > N$ when $\alpha_j \neq \alpha_i$. Hence, Ω may be smaller or larger than zero when there is an interior solution with emissions trading. If there is no interior solution with emissions trading, we do not know whether $\alpha_j^{cn}/\alpha_i^{cn}$ is larger or smaller than $\alpha_j^{ct}/\alpha_i^{ct}$, so that Ω can be larger or smaller than zero. $\square$

It may seem counterintuitive that when countries cooperate emissions trading may lead to higher total emissions. After all, emissions trading should lead to lower overall costs of abatement and thereby to an incentive to cut emissions. However, the Nash bargaining solution tries to reach an outcome where all countries receive the same gain from cooperation. Then, when marginal damage of emissions of the low-damage countries is very low, a decrease in emissions will not lead to a large increase in welfare. To reach the same increase in welfare as the high-damage countries, low-damage countries then have to increase the number of permits beyond the level without trading.

Welfare

For the welfare effect of emissions trading we find

Proposition 12 *Assume that $C_i(e^*) = C_j(e^*)$ for all $e^* \geq 0$ and all $i, j \in N$. Then, if there is an interior solution with emissions trading, total welfare* *always increases as a result of emissions trading and low-damage countries always gain, while high-damage countries may lose from emissions trading.*

Proof Define $\Pi(\bar{E}, \mathbf{e}) = \sum_{i=1}^{N} W_i(\bar{E}, e_i)$, where $\mathbf{e}$ is the vector of individual emissions. From Proposition 8 we know that the interior solution gives the full cooperative solution, which by definition leads to maximum total welfare. So we must have that $\Pi(\bar{E}^{ct}, \mathbf{e}^{ct}) \geq \Pi(\bar{E}^{cn}, \mathbf{e}^{cn})$. For the interior solution, it holds that $\frac{\alpha_{h_i}^{ct}}{\alpha_{l_i}^{ct}} \geq \frac{\alpha_{h_i}^{cn}}{\alpha_{l_i}^{cn}}$ since from Proposition 7, $\alpha_{h_i}^{cn} < \alpha_{l_i}^{cn}$ and $\alpha_{h_i}^{ct} = \alpha_{l_i}^{ct}$. Combining this with $\Pi(\bar{E}^{ct}, \mathbf{e}^{ct}) \geq \Pi(\bar{E}^{cn}, \mathbf{e}^{cn})$ it then follows that $W_{l_i}(\bar{E}^{ct}, e_{s_i}^{ct}) \geq W_{l_i}(\bar{E}^{cn}, e_{s_i}^{cn})$ and that $W_{h_i}(\bar{E}^{ct}, e_{b_i}^{ct})$ may be larger or smaller than $W_{h_i}(\bar{E}^{cn}, e_{b_i}^{cn})$ depending on the size of the increase in total welfare and on the redistribution of welfare over the countries. □

The intuition behind the result is that when countries behave cooperatively, emissions trading always leads to higher total welfare. However, emissions trading gives rise to side payments from buyers of permits to sellers. So in all, the cake to be divided among the countries has increased as a result of emissions trading and sellers of permits receive a larger part of the cake. Hence, sellers always gain from trading. Buyers of permits on the other hand receive a smaller part of the cake under trading. They may then lose from trading if they receive substantially less than in the no trading case. Of course, they still gain compared to the non-cooperative equilibrium.

Hot Air

In the non-cooperative model, sellers often receive hot air. That is, their emission ceiling with emissions trading is often higher than their emissions ceiling without emissions trading. To see when a seller receives hot air in the cooperative model, we must compare the ceiling of a seller in the cooperative outcome with emissions trading with the ceiling of a seller in the non-cooperative outcome without emissions trading.

Using the Mean Value Theorem (see Sydsæter and Hammond 1995, p.

222), define:

$$\hat{C}_i'' \equiv \frac{C_i'(e_i^{ct}) - C_i'(\bar{e}_i^{nt})}{e_i^{ct} - \bar{e}_i^{nt}} \tag{2.35}$$

We can then derive

Proposition 13 *In the cooperative equilibrium, a seller will set* $\bar{e}_i^{ct} > \bar{e}_i^{nt}$ *when*

$$\sum_{j=1}^{N} \frac{\hat{C}_i''}{C_j''(e_j^{ct})} > \frac{\sum_{j=1}^{N} \frac{\alpha_j^{ct}}{\alpha_i^{ct}} \left[D_j'(\bar{E}_j^{ct}) + P'(e_j^{ct} - \bar{e}_j^{ct}) \right] - D_i'(\bar{E}_i^{nt})}{P'(e_i^{ct} - \bar{e}_i^{ct})} \tag{2.36}$$

Proof From (2.35), we have:

$$\bar{e}_i^{ct} - \bar{e}_i^{nt} = \bar{e}_i^{ct} - e_i^{ct} + \frac{C_i'(e_i^{ct}) - C_i'(e_i^{nt})}{\hat{C}_i''}$$

Thus:

$$\bar{e}_i^{ct} > \bar{e}_i^{nt} \Leftrightarrow \left[\hat{C}_i'' + \frac{C_i'(e_i^{ct}) - C_i'(\bar{e}_i^{nt})}{\bar{e}_i^{ct} - e_i^{ct}} \right] \frac{\bar{e}_i^{ct} - e_i^{ct}}{\hat{C}_i''} > 0$$

For sellers (with $\bar{e}_i^{ct} > e_i^{ct}$), $\bar{e}_i^{ct} > \bar{e}_i^{nt}$ when:

$$\hat{C}_i'' + \frac{C_i'(e_i^{ct}) - C_i'(\bar{e}_i^{nt})}{\bar{e}_i^{ct} - e_i^{ct}} > 0$$

Substituting (2.1), (2.25) and (2.27), this becomes:

$$\hat{C}_i'' > \frac{\sum_j \frac{\alpha_j^{ct}}{\alpha_i^{ct}} \left[D_j'(\bar{E}^{ct}) + P'(e_j^{ct} - \bar{e}_j^{ct}) \right] - D_i'(\bar{E}_i^{nt})}{\bar{e}_i^{ct} - e_i^{ct}}$$

Dividing both sides by $-P'$ and substituting (2.10) gives (2.36). $\square$

To see when a seller is likely to receive hot air, consider the LHS and RHS of (2.36) in turn. A seller is more likely to receive hot air when the LHS of (2.36) is large. Recall, that the LHS can be written as $\hat{C}_i''/-P'$ (from (2.10)). This is large when the marginal costs of abatement rise sharply with a decrease in emissions and when the price function is rather flat. In that case, the country can lower costs by increasing the emissions ceiling. At the same time, the country does not have much incentive to increase the price of permits since the price function is very unresponsive.

A seller is also more likely to receive hot air when the RHS of (2.36) is small. This is the case, when total emissions in the cooperative equilibrium are much smaller than total emissions in the non-cooperative equilibrium. In this case, the country will not decrease its welfare by much when increasing its amount of permits.

To sum up, in the Nash bargaining solution with emissions trading, a seller is most likely o receive hot air when the international environmental agreement has led to substantial emission reductions and the gain to the seller from the increased endowment of permits does not come at high costs to the other participants in the agreement.

2.4 Conclusions

This chapter has analyzed the effect of international emissions trading on the choice of national emission ceiling by the countries involved. It was shown that when emissions trading is allowed, countries will alter their abatement commitments which affects total emissions and welfare. As this chapter shows, emissions trading can lead to both lower and higher total emissions and in the case of non-cooperative behavior, also to lower total welfare compared to the non-cooperative equilibrium without emissions trading.

We have discussed three cases: 1) countries behave non-cooperatively and cannot affect the price of permits through their emission ceiling, 2) countries behave non-cooperatively, but have market power, and 3) countries behave cooperatively. In all cases, the permit market is assumed to be perfectly competitive, which would be the case if all countries leave the trading of permits to their firms.

In the first case, we show that when countries are heterogeneous, an equilibrium with all countries behaving as price takers is not possible. The country with the lowest marginal damage will supply all permits and therefore is a monopolist. Only when there are enough countries with the same and lowest marginal damage will it be possible to have perfect competition. These lowest cost countries will then be the only countries issuing permits. We have shown that that the permit-issuing countries set a higher total emission ceiling than under no emissions trading, while the other countries set their emission ceiling equal to zero. In this case, emissions trading will lead to an increase in total emissions compared to non-cooperative abatement without emissions trading. Welfare of the countries involved may well decrease in this case, because of the increase in total emissions.

In case two, countries have market power. This means that they can influence the permit price through the emission ceiling they set. In that case, the effect of emissions trading on the individual emission ceilings becomes more complex. In essence, there are two opposing effects that derive from the fact that a buyer faces lower, while a seller faces higher marginal abatement costs with international emissions trading than without. The higher marginal abatement costs will induce a seller to set a higher emission ceiling. However, because the country has market power, it tries to manipulate the price by decreasing the volume of permits in the market. This causes a seller to set a lower emission ceiling. On the other hand, the lower marginal costs are for the buyer, the lower he would like to have the emission ceiling. But he also tries to keep the permit price low and that is an incentive for the buyer to set a higher emission ceiling. The total effect depends on the strength of these two effects for buyers and sellers respectively. Therefore, total emissions may decrease, but may also increase as a result of emissions trading. It may happen that an interior solution does not exist. If that is the case, there will be a boundary solution in which at least one country that does not issue permits. This leads to higher total emissions than in the interior solution where all countries issue permits. In general, welfare will increase for all countries when total emissions decrease, but may decrease when total emissions increase as a result from trading. Evidently, the presence of market power does somewhat mitigate the impact of emissions trading on individual emission ceilings, total emissions and welfare. Now at least, international emissions trading can lead to lower total emissions.

In the third case, countries behave cooperatively. However, side payments are not possible. We use a Nash bargaining approach to define the cooperative equilibrium and to model the effect of emission trading. Here, the effect of emissions trading becomes even more complex. Now countries also take the effect of their own emissions on other countries into account, and the extent to which they do so may change when going from the no-trading regime to the trading regime. However, also here, countries may set a lower or higher emission ceiling and total emissions may decrease or increase as a result of emissions trading. In this case, sellers of permits always gain from a shift to emissions trading, while buyers of permits may see their welfare decrease. This is different from the previous cases where emissions trading could lead to lower welfare for both buyers and at least some sellers.

The analysis in this chapter shows that hot air, meaning that a seller sets an emission ceiling in excess of its actual emissions, is a common consequence from the introduction of international emissions trading. In the two non-cooperative equilibria analyzed here, sellers virtually always receive hot air. In the cooperative solution, hot air is not as common, but is still possible when the international environmental agreement leads to substantial emission reductions and the endowment of hot air does not affect the permit price substantially.

The analysis shows that emissions trading is more likely to lead to an increase welfare when the marginal damage and abatement costs curves of seller countries are relatively flat. This seems to be the case in the Kyoto protocol (see Ellerman and Decaux 1998), which would indicate that the inclusion of emissions trading has led to lower overall emissions and higher welfare.

There are several extensions possible to this chapter. First of all, we found that some countries may experience a decrease in welfare as a result of emissions trading. It is possible then, that such countries would want to block any agreement on emissions trading, or at least would want to block the entry of certain countries to the emissions trading scheme.

This leads to another possible extension, namely that emissions trading is only allowed between a subgroup of countries, possibly only the stable coalition. In the cooperative solution, there is another possibility. In our analysis, we have assumed that in the cooperative solution with emissions trading, countries use the noncooperative equilibrium without emissions trading as the threat point. We then found that welfare in the Nash bargaining solution with emissions trading could be lower for some countries than their welfare would be in the Nash bargaining solution without emissions trading. However, if instead the countries used the cooperative solution without trading as a threat point, emissions trading would always lead to higher welfare for all countries. The reason for this is that in the Nash bargaining solution, countries can never receive less than the payoff in the threat point. Hence, by using the Nash bargaining solution without emissions trading as the threat point, no country will be worse off after the introduction of emissions trading. Which of the two scenarios is the most appropriate one is open for discussion. It should however be noted, as we did in the introduction, that for some countries, e.g. the US, the inclusion of emissions trading in the Kyoto protocol was a precondition for signing it.

Another issue is hot air. As this chapter shows, sellers often receive hot air, especially in the non-cooperative case. However, there is much resistance to the possibility of trading hot air. Within the current model, one could analyze the effect of emissions trading with the additional restriction that hot air is not possible.

Chapter 3

Alternative Design Options for Emissions Trading: A Survey and Assessment of the Literature

3.1 Introduction

The Kyoto Protocol of 1997 sets ceilings for the emissions of greenhouse gases of Annex B Parties to be achieved in the commitment period 2008-2012. For some parties, such as the US and EU, keeping emissions below their assigned amounts will imply high marginal costs whereas others, for example Russia and Ukraine, can realize their emission targets with little economic effort. Article 17 of the Kyoto Protocol introduces flexibility by allowing international emissions trading in greenhouse gases. Parties can avoid high marginal cost of emission reduction by buying their assigned amounts from countries which accept an equivalent decrease of their assigned amounts since they are able to expand their emission control at relatively low marginal cost.

In the political discussion, international emissions trading is seen as transactions between national governments, increasing or decreasing their assigned amounts. After the revision of the national emission targets, adequate national policies and instruments should be designed and implemented to realize the revised targets. On the other hand, economists who have reflected and written on international emissions trading have pointed out that the flexibility of the Kyoto Protocol and cost savings would be much higher if international emissions trading between private parties is made feasible: private parties have better information than governments on their emission control costs, as well as the incentive to keep costs as low as possible.

Private party trading means that a firm in country X can buy or sell emission permits from, respectively to a firm in country Y. It sets the stage for a truly international market for tradeable emission permits; the tasks of national governments being restricted to registering the concurrent changes in assigned amounts and to monitoring and enforcing compliance of national firms.

This type of trade in emission allowances between private parties under Article 17 of the Kyoto Protocol should be clearly distinguished from Joint Implementation as defined in article 4. Although J.I. also involves a transaction between private parties residing in Annex B countries, allowing one party (in the donor country) to increase its emissions thanks to the extra emission reduction by the other party (in the guest country), its design is basically different and its economic impact as well.

In this chapter we shall discuss the design of government trading and two types of private trading; permit trading and credit trading. With permit trading, a cap is placed on firm and total emissions, after which firms are allowed to trade emission allowances. Credit trading on the other hand is based on relative standards with no absolute cap on emissions. In our analysis we concentrate on emissions of carbon dioxide and on the type of design that offers the legal setting for transactions between private parties. Quite understandably the literature on the subject focuses on the international dimension. Yet adequate functioning of the international flexibility mechanisms highly depends on how well the national instruments are designed and implemented. This simple truth is often overlooked. In this contribution we shall therefore concentrate on the national basis of international permit and credit trading.

Among economists (see Ellerman 1998; Bohm 1999; Hahn and Stavins 1999; Zhang and Nentjes 1999) there is a consensus that international permit trading between private parties makes only sense if it is embedded in well-enforced national schemes of tradable permits. Consequently international emissions trading is basically private party trading within internationally linked national schemes of tradable emission permits. Various designs of national permit trading schemes have been proposed in the past few years. We shall give a survey in section 3.3 and discuss their strengths and weaknesses, selecting what we consider to be the major issues. The link between national cap and trade schemes and international emission trading is addressed in section 3.4.

Although the interest in tradeable permit schemes is growing, direct regulation still is the dominant national instrument of environmental policy; for air pollution usually in the form of performance standards. To meet the bottlenecks caused by the rigidity of direct regulation, flexibility has been introduced in the US by allowing trade in emission reduction credits. Whereas it is normally argued that credit trading has to be based on explicit abatement arguments, we show in this chapter that this need not be. Actually, credit trading can be organized in much the same way as permit trading. This also extends to the international level, where international credit trading can be set up by linking national trading schemes. The result is that international credit trading does not fall under article 4 of the Kyoto Protocol, but under article 17, which defines emissions trading. The particularities of national credit schemes and the major differences with cap and trade programs will be discussed in section 3.3.2 and Joint Implementation as international credit trading is the subject of section 3.4.2.

3.2 Government Trading

One view of international GHG emissions trading is that the trading entities should be governments. In this case, trading is a transfer of assigned amounts and the commitments of the trading countries change accordingly. These changes in commitment will have to be reflected in changes in domestic policy. The buyer of emission quotas can relax its policy, while the seller will have to tighten policy. Altering environmental policy will take time, in many cases much time. This is a feature of government trading that has a profound impact on the design of this trading scheme

It is to be expected that government trading will take place in the early stage when national reduction policies are designed and at a late stage shortly before or in the commitment period 2008-2012. Presently national governments are planning what measures have to be taken to be able to comply in the commitment period. Discovering that marginal costs of emission reduction are going to be quite high, like in the Netherlands, they will look for possibilities to raise the national emission ceiling by purchasing emissions at a price below their marginal costs. Other governments will discover they are able to sell emissions since the cost of national emission reduction will remain low. To avoid changes in environmental policy later on, governments will try to conclude the trades before the national policies are set. Before and in the commitment period, some governments will discover they are not going to comply, since planning can never be perfect in the face of an unknown future. Other governments may expect overcompliance. Again, they will see an opportunity to trade: not for reasons of efficiency, like in the planning stage, but for compliance.

The most likely scheme of government trading to arise is bilateral trade in big quantities, since this is the least complex way of doing business and saves transaction costs. For the reasons mentioned, one also expects trade to be rather infrequent. Also remind that only the 38 Annex B countries can trade. Hence, there are relatively few traders. Because of the restricted number of trades, probably clustered in the beginning and at the end of the period 2000-2012, we shall not see a well performing market with regular price signals.

3.2.1 An Analysis of Government Trading

The performance of government trading depends on several factors such as cost efficiency, flexibility and complexity of the scheme. As will become clear, government trading does not perform equally well on these points, but has some distinct strengths and weaknesses.

In general, government trading will lead to improvements in cost efficiency in the trading countries, especially when trading occurs in the planning phase. Countries with relatively high marginal costs of abatement can lower costs through the purchase of emission quotas from countries with lower marginal costs. After the trade, the marginal costs in the two trading countries will be more equal than they were before.

Although government trading will improve cost efficiency, it will not minimize costs. There are two major reasons for this. The first is the lack of information on the part of the government about the abatement costs of the emission sources. This can be called the domestic factor, since it only depends on factors that are internal to the country. The other, international, reason is that there are only a limited number of traders in a pure government trading system. Because of this, it is likely that the market is thin and that some, or all countries can behave strategically.

The information governments collect when planning their emission reduction measures, including the purchases and sale of emissions abroad, will be on a high level of aggregation. It will also be incomplete and uncertain. This makes that the government's estimate of how much emissions to trade at a certain (minimum or maximum) price is unreliable and not necessarily the most cost-effective choice. Such an estimate is made even more difficult by the fact that it may be quite unclear what price can be fetched before the emission exchange contract between governments has been concluded.

How serious this problem is depends on when government trading occurs and on which instrument is used domestically. If the government wants to trade emissions before any policy is applied, any estimate of marginal abatement costs will be very uncertain. If on the other hand the government has regulated the emissions of greenhouse gases, the estimates can be more precise. This will especially be the case when tradable permits are used. Through such a system, the marginal abatement costs of the emission sources will be revealed to the government, making it easier to assess whether a certain trade is profitable or not. However, implementing the instrument before the start of international emissions trading leads to higher administrative costs since now the distribution of the total emission ceiling over the emission sources has to be performed more than once.

After the trade of emissions, governments have to allocate emissions or emission reductions nationally. How this is done depends on the instrument applied. However, the lack of information on the side of governments will lead to an inefficient outcome, unless tradable permits or emission charges are used (see Bohm and Russell (1985) and Barde (1995) for a discussion of national instruments). With command and control instruments, an emission level has to be set for every emission source. Since this cannot be done perfectly without full information, abatement costs will differ per emission source. Although taxes will lead to an efficient outcome, it is hard to determine the optimal tax level without perfect information, hence taxes may not lead to the desired abatement level. Only with tradable permits will the desired abatement level be realized with certainty in an efficient manner (Weitzman 1974).

The second major problem connected with a government trading system is the small number of traders in the market. In effect, only the 38 Annex B countries can participate in emissions trading. The number of countries actually trading will be even less, partly because for some countries, not much can be gained from trading, partly because a number of countries will not ratify the Kyoto Protocol. The problem is further aggravated by the fact that the trades that will occur will be large and infrequent. All of this gives rise to some problems. Firstly, it is very likely that the market for emission quotas will be thin, which makes it hard to retrieve information from the market. Secondly, some countries will be able to exert market power.

A market is said to be thin when only few transactions take place in the market and trades take place infrequently. In such a market no real market price will develop; prices will only be known after each trade, that is if the traders are willing to reveal it. As the number of traders in a government trading scheme is small and the trades will be large and infrequent, it is very likely that a government trading scheme will lead to a thin market in emission quotas. As is shown by Diamond (1982), Howitt and McAfee (1987,1988), and Liski (1999), thin markets are not efficient in general. There are two reasons for this. Firstly, the trades that come about will hardly ever be conducted at the price that would arise in a competitive market. Hence, trades will not be efficient. Secondly, countries cannot a priori be certain at which price the trade will be conducted, and hence whether trade will be beneficial for them. Therefore, some countries may choose not to trade, although benefits could be reaped from trade. The uncertainties about national marginal costs of emission reduction and about the price of emissions makes that marginal costs will not be equalized between countries, since the uncertainty will give a bandwidth around the actual marginal costs within which the country will not trade.

In an international emission market, market power can be defined as the possibility of a seller (buyer) of quotas to sell (purchase) the quotas at a price above (below) the market price with perfect competition. As Hahn (1984) and Westskog (1996) show, the market power of a country is dependent on the demand or supply of permits by a country. This in turn depends on the difference between the optimal amount of permits for a country, and its initial emission quota. If the difference between these is large, the demand or supply of that country becomes large. Besides this, the total number of permits, or the size of a country, will have an influence. Small countries with a large deviation between optimal number of permits and emission ceiling are not likely to have much market power. A large country with a large difference between initial quota and equilibrium emission level will be more likely to exert an influence on the price of emission quotas, either by acting as a monopolist or as a monopsonist. In both cases the equilibrium price of permits will be different from the price that would occur in a perfectly competitive market, which leads to a suboptimal outcome.

How real will the problem of market power be in the coming trading period? Ellerman and Decaux (1998) analyze several emissions trading scenarios. When only emissions trading between Annex B countries is considered the former Soviet Union (FSU) accounts for virtually all exports of emission quotas (345 out of 351 Mton). It is however unlikely that the FSU will act as a single unit. On the other hand, Russia and the Ukraine will probably supply the main part of the emission quotas, with Russia being the largest of the two. On the buying side, the US, Japan and the EU are of about equal size (106, 95 and 106 Mton respectively). Hence, if the EU can act as a single unit, there are three large buyers. However, it is more likely that the EU countries will trade separately. In that case, we have one very big seller (Russia) and two big buyers (the US and Japan) with a rather large competitive fringe on the buying side. When not only trade between Annex B countries is possible, but also trade with non-Annex B countries through CDM, the picture changes drastically. In that case, the total volume of trade becomes much larger (935 Mton) and the FSU only supplies about 20% of the emission quotas, while China will provide about 45% (437 Mton). The US will be the biggest purchaser (390 Mton) followed by the EU (234 Mton) and Japan (132 Mton). In both scenarios then, some large buyers and sellers exist. Especially in the first case, market power on the seller side may cause a problem since virtually all quotas will be supplied by the FSU.

Another impediment to an efficient outcome is the presence of transaction costs, and the costs connected with gathering information (see Stavins 1995). Both types of costs are likely to be high per transaction with government trading. As is argued above, information about other countries' abatement costs will be imperfect and some efforts may be used to gather data on costs to improve knowledge. Furthermore, negotiations are needed to reach an agreement on the quantity and the price of the trade. However, since we expect the quantity of trade per transaction to be large, these costs will not be large per unit of emissions traded. It is however important to note that the transaction costs depend crucially on the design of the international trading regime (Woerdman 2001). If many conditions have to be fulfilled before a trade is allowed, or if restrictions are set on trading, transaction costs will be increased. This would not be a problem exclusive to government trading, but would be felt in all forms of international emissions trading.

The above shows that government trading is not a perfect trading scheme. It brings improvements in cost efficiency, but does not deliver full efficiency. Government trading does however possess certain characteristics that make it an attractive trading scheme despite the disadvantages.

Since government trading will only alter the commitments of the trading countries, it does not affect the choice of policy instrument that can be implemented domestically. This is rather different from the private trading schemes that will be discussed later where the trading scheme fixes a domestic instrument. With government trading then, the instrument of regulation can be chosen freely. This may be an advantage if the country or some major interest groups for some reason have a preference for an instrument other than tradable permits or domestic credit trading. Some countries may also want to prevent trading with countries that have weak enforcement policies or that can trade 'hot air' (see below).

A system of government trading is also attractive because it does not require a long preparation time. No additional rules for monitoring and enforcement are needed, besides those that are needed for monitoring compliance with the Kyoto Protocol anyway. Hence, trade can take place almost instantaneously. In fact, trade can already commence before national regulations are implemented.

The complexity of the government trading scheme is rather low. In most cases, only two countries will be involved in a transaction, although multilateral trade, as within the EU is possible. The fact that trade is between countries makes monitoring relatively easy. Government trade is a transfer of GHG quota between countries. Hence, it changes the emission ceiling of the trading countries. During the commitment period, governments have to report their actual emissions of GHG gases and the size of their emission quota to an international agency. However, this would also have to be done in the case without international emissions trading. Government trade therefore does not lead to additional monitoring costs compared to a situation without trade.

The Kyoto Protocol has raised the problem of 'hot air'. With hot air is meant that some countries have received a higher emission ceiling than their actual emission level will be. Hence, these countries can sell emission quotas without having to reduce emissions domestically. The result is that aggregate emissions will be higher with trade than without trade. With government trade, it is very likely that hot air will be sold, thereby reducing environmental effectiveness. For this reason, restrictions on emissions trading have been proposed by many, for example the EU and environmental organizations (see Boom and Svendsen 2000b; Woerdman 2002). It is however very unlikely that the countries that benefit most from trade in hot air will accept such restrictions without a change in their commitment.

Government trading brings about improvements in efficiency, but does not lead to a fully efficient outcome. However, government trading has some distinct advantages. Probably the main advantage is that it leaves countries completely free in their choice of national instrument. Furthermore, it is a simple and straightforward trading scheme that is easy to understand and gives governments greater possibilities of control over the trading partners than a scheme of private emissions trading allows. The latter advantages make that government trading is a politically highly acceptable trading scheme.

3.3 Private Emissions Trading

With private emissions trading the trading entities are private parties such as firms and households. In the following we will discuss two types of private trading: permit trading and credit trading. In permit trading, a ceiling, or cap, is placed on total emissions, after which tradable permits to the amount of the ceiling are distributed to some parties. In credit trading, emission sources are regulated through a relative standard prescribing some emission level per unit of output or input. Credits can than be sold for so far as a source stays below this relative standard.

Whereas government trading does not put restrictions on the choice of national policy instrument, international private trading schemes, such as permit and credit trading, are feasible only when they are crafted on private emissions trading as national instrument. This makes it necessary to discuss the design of private trading systems at the national level before analyzing the pros and cons of international trading schemes. As will be shown below, both permit trading and credit trading can be designed in different ways, which may have an impact on the performance and acceptability of the schemes at the international level.

3.3.1 Design of a national permit trading scheme

The basic elements of a scheme of tradable emission permits at the national level are the following: set a ceiling on total emissions of the group of participants in the scheme; distribute the emission permits among participants; allow trade; monitor (transfer of) emission permits and of actual emissions and enforce compliance with he scheme. Differences between proposed schemes arise from differences in how these elements have been worked out.

Since carbon dioxide is released by burning the carbon contained in fossil fuels emissions can be controlled by restricting the use of (carbon in) fossil fuels. In the discussion on appropriate design of tradable carbon permit schemes a major issue is at what level to organize it.

Four basic designs of permit trading can be distinguished (Jepma et al. 1998; Hargrave 1998): upstream, downstream, hybrid and mixed approaches. In an upstream scheme, the producers, processors and transporters of fossil fuels are regulated. In a downstream scheme, the consumers of fuels can trade emissions and in a hybrid scheme large consumers of fossil fuels are directly regulated, while the remainder of fuel consumption is regulated through an upstream scheme. In a mixed scheme, large emitters are regulated through a tradable permit system, while small emitters are regulated through some other instrument. These four schemes and an alternative scheme will be discussed below.

Several criteria have to be taken into consideration in the evaluation of the four design options (Hargrave 1998; Hargrave et al. 1999)

- *Environmental effectiveness* The larger the coverage of total carbon dioxide emissions of the scheme, the greater the certainty that the emission level set by the government is realized.

- *Economic efficiency* Economic efficiency depends on the coverage of emissions in the scheme and on the number of sources captured.
- *Effects on competition* Competition can be distorted when competitors do not face the same marginal costs of abatement.
- *Administrative burden* Intricate systems increase the costs of setting up and maintaining the trading scheme. The administrative burden depends on (Hargrave 1998)
  1. The number of regulated sources. The larger the number of sources, the more information is needed in the setting up of the system.
  2. The availability of needed data. If the data is readily available, the previous point becomes less important.
  3. The level of reporting requirements and the level of monitoring needed. If reporting requirements are very intricate, the costs for the regulated sources are high. High levels of monitoring mean high costs for the monitoring authority.
  4. Proper accounting. Ideally, firms are only required to hold emission quotas for emissions of greenhouse gases, and only for domestic emissions.
- *Relationship to exiting policies and measures* When not all emissions are captured by the trading scheme, but some are regulated through other instruments, the interaction between the systems can have both environmental and economic consequences.

Upstream Approach

In an upstream approach, not the emitters of carbon receive permits, but instead the suppliers of fossil fuels have the obligation to cover their fuel sales (in terms of carbon) with permits. Producers, processors, and distributors of oil, coal and natural gas receive permits for free or buy them at an auction. After the initial distribution, they can trade the permits amongst each other. The price of permits, which will result in the market, will be passed on to the consumers through the price of fossil fuels. Hence, the consumers pay a kind of 'carbon tax'. The result is that fuels with higher carbon content, such as oil and coal, will rise more in price than those with a low carbon content, such as natural gas.

Two main advantages of an upstream approach can be identified (Hargrave 1998; Jepma et al. 1998; Bohm 1999). First, an upstream approach would comprise virtually all fossil fuel use, and thereby carbon emissions. A second advantage is that there are relatively few regulated entities in such a system and only their carbon sales have to be monitored and compared with the permits the suppliers have acquired. Therefore, the administrative costs of an upstream system will be low.

Several disadvantages of an upstream system are mentioned in the literature. The main problem with an upstream approach is the low political acceptability of such a scheme. Since here are (almost) no options for the suppliers of fossil fuels to reduce the carbon content of the fuel, the carbon cap is actually a fuel cap. According to Hargrave (1998), this may induce strong resistance from producers since it will affect their profits. This is, however, not a very strong argument since any measure to curb greenhouse gas emissions will affect the producers and suppliers of fossil fuels. The resistance against an upstream system is more likely to be connected with the way of distributing the permits.

If in an upstream system the permits were to be grandfathered, the receivers of the permits would be rewarded a large rent. Since they will transfer the main part of the costs of the permits to the end-users, the permit holders do not pay for the reduction of emissions in any direct way (Cramton and Kerr 1998). In this way, a small group of producers and transmitters of fossil fuels receive large rents without incurring costs. Although grandfathering might change producers into enthusiastic supporters of the scheme (see Dijkstra 1999 and Svendsen 1998b), it will have the same distributional impact on end users as a carbon tax. It is, however assessed that it is not politically acceptable that such large rents are distributed to a relatively small group of large companies (Cramton and Kerr 1998; Hargrave 1998; Woerdman 2000). This leaves open the option of auctioning the permits. However, this will meet resistance from the affected sectors: the suppliers as well as the end users. Since there are relatively few suppliers that will be involved, they will be very effective at organizing themselves (see Olson 1965). It is therefore likely that they will have an influence on the policy outcome. The same is true of the few very large energy intensive end users.

Besides this principal political bottleneck, several other disadvantages of upstream trading are mentioned in the literature. One of the arguments is that consumers have no incentive to reduce their emissions of carbon other than through the reduction of fuel use. Hence, techniques aiming at removing carbon after the fuel has been used (end of pipe technologies) will not be developed (Hargrave 1998). In our view, this could be easily solved, by introducing refunding for carbon removal after fuel use. An other somewhat peculiar argument runs that an upstream approach may not provide as great an incentive for energy efficiency and fuel switching as a downstream approach. The argument is based on the assumption that energy consumers do not respond to price signals in the same way as to quantity signals. Hargrave (1998) does however not give any references to confirm this view. Hence, it is not certain whether this is a certified fact, or just an opinion. Finally, it is mentioned that the low number of participants in the scheme increases the possibilities for market power by one or a few participants (see also Jepma et al. 1998). It is assessed though that market power would not be a problem in the US, since the number of regulated firms in an upstream system would be about 2000, with the largest firm having a market share of about 6% (Cramton and Kerr 1998). According to Koutstaal (1997), even in a small country like the Netherlands there would be 40 to 50 traders in an upstream scheme, which should be sufficient for a viable permit market.

We conclude that upstream schemes have the attractive features of wide coverage and low administrative costs. However, they meet the political obstacle that grandfathering as well as auctioning of the permits will meet strong resistance form interest groups.

Downstream

In a downstream system, all emission sources are required to hold emission permits and the emissions of all sources will be monitored. The government can either distribute the permits for free (grandfathering), or auction the permits. In all permit trading schemes so far, the permits have been grandfathered (see UNCTAD 1998; Stavins 2000). The reason for this is that it enhances the political acceptability of the scheme.

One of the major issues in permit trading is the distribution of the permits. Basically, the government can choose to auction the permits or it can give the permits away for free (grandfathering). The two methods of distribution give the same permit price and lead to the same efficiency of the system. However, each has some specific advantages and disadvantages. Some central issues are the so called 'double dividend' effect and the political acceptability of the scheme. With the double dividend is meant that the revenue of an environmental tax or an auctioned tradable permit system can be used to reduce distortionary taxes elsewhere in the economy. In that way, damaging emissions are reduced, while at the same time the economy is made more efficient through a lowering of distortionary taxes (Bovenberg and de Mooij 1994; Bovenberg and Goulder 1996; Goulder et al. 1997; Parry et al. 1999). Seen in this way, instruments that generate a revenue may be preferred to those that do not raise a revenues. Another use for the revenue may be to distribute it to the parties affected most by the regulation. This would enhance the political acceptability of the scheme. However, the revenue may also be used for more distortionary subsidies or consumption. In that case, the revenue-raising capacity of an auctioned system may be seen as a disadvantage. Hence, in comparing the two ways of permit distribution, one needs to know specifically what the revenue, if any, will be used for, before one can make an assessment (Bohm 2002).

Besides full efficiency, downstream trading has the advantage that it is highly politically acceptable. Since the system regulates those that have to reduce the emissions, and thereby incur the costs for doing so, it will be rather acceptable to grandfather the permits, even though this implies the distribution of a rent for free. Grandfathering the permits will make the scheme much more acceptable for the regulated parties than distribution through an auction (Hargrave 2000).

However, the political acceptability gained through grandfathering comes at a cost. First of all, grandfathering may act as a barrier to entry in the regulated sectors. If permits are grandfathered, incumbent firms in the industry receive their permit for free, but new entrants must buy permits from the incumbents to be able to produce. This then imposes higher costs on new entrants than on incumbents. This line of reasoning has been criticized for ignoring the fact that firms should take the opportunity costs of permits into account. That is, a permit, received for free or bought at a price, represents a value in that it could be sold on the market at the going rate. Using a permit for covering emissions implies sacrificing the revenue from selling the permits, which is a cost. Seen in this way, it makes no difference for firms whether they receive permits for free, or have to buy them on an auction or on the market. The only difference is that the shareholders receive a one off bonus. However, Koutstaal (1997) has argued that under certain conditions grandfathering permits to incumbents can raise barriers to entry. Interest rates on loans often depend on the share of own capital in total capital of a firm, grandfathered permits then make it easier for the incumbents to borrow money than for new entrants and in this way, they gain a competitive edge over new entrants. It is clear that such an advantage for incumbents would be lost immediately when the government decides to auction all permits. Another problem with grandfathering permits is that a distribution rule has to be decided on. If the permits are auctioned, all the government has to do is to set the total amount of permits and auction them. With grandfathering, the government has to decide whether to distribute the permits on the basis of historical emissions, on output, on future expected emissions or output, or on some other basis. Then, it has to be decided how to distribute them over the participating emission sources. Such a process invites lobbying and even lawsuits against the regulator, slowing down the regulatory process and increasing the costs of regulation.

Next to grandfathering a second factor increasing the acceptability of downstream trading, which pertains in particular to the US, is the familiarity with the system (Festa 1998). In the US, several kinds of downstream trading (credit and permit trading) have been used (see Tietenberg 1989; Klaassen and Nentjes 1997; Svendsen 1998b; Schmalensee et al. 1998 for some assessments). However, downstream trading is also known in Europe, for example in the milk production and fishing quota in the EU and manure production quota in the Netherlands (Boom et al. 1998; Stavins 2000). The familiarity with the system will make the system easier to explain and might diminish resistance from politicians and bureaucrats. In a downstream system, all individual emission sources are regulated. This means that there are many traders facing the same price, trading will be regular, making that new information is dispersed quickly through the market and there is little risk of market power (Jepma et al. 1998). The size of the market will also make the development of derivatives such as options possible which will make the market even more efficient.

Besides these, some other advantages of downstream trading are mentioned in the literature. According to Festa (1998) a downstream system is a greater stimulus for innovation than an upstream system. Festa asserts that price signals are not always sufficient motivation for consumers to implement profitable energy savings but that quantitative signals are sufficient motivation. Again, there is no evidence provided to support this claim. Another argument related to innovation, is that a downstream system where emissions are monitored at the sources also provides incentives to remove carbon, after emission use (Festa 1998).

Although the literature endows a downstream system with many advantages, some disadvantages are mentioned too. There is an almost general consensus that there are high administrative costs connected with a downstream approach (Festa 1998; Hargrave 1998; Jepma et al. 1998). One of the reasons for this is that the permits have to be distributed to all the sources and their emissions have to be monitored. If the distribution is based on historical emissions per source, the distribution will be very costly, since then the government needs to know the emission data from all sources for some period in the past. Although this already will be costly, the monitoring of the emissions and checking of compliance by comparing permits and emissions at every source will be extremely expensive.

One remedy to this problem would be to lower the coverage of the system by including only large sources or specific sectors. Other sources and sectors would of course have to be regulated with other instruments. That could contain the problem that the burden of emission reductions would fall solely on the firms placed under a cap and reduce carbon leakage as well (Hargrave 1998).

In summary we conclude that a major argument for downstream systems is the possibility of grandfathering; thus reducing the opposition from interest groups against restriction of carbon use. But on the other side the high administrative cost of a pure downstream system thwarts the feasibility of such a scheme.

Hybrid

In a hybrid system, large polluters are regulated directly as in a downstream system, while other polluters are targeted through an upstream system (Koutstaal 1997). Hybrid trading can be seen as a compromise system between upstream and downstream trading, giving low administrative costs and a reasonable level of political acceptability.

An advantage of a hybrid system is that the number of parties to be monitored and to be checked on compliance is relatively low so that the administrative costs of the system are low, although larger than in an upstream system. It will also secure a reasonable number of traders making the system more efficient and flexible (Jepma et al. 1998). At the same time, the environmental effectiveness of the scheme is high because all sources are covered; the large sources directly through the downstream part and the small sources indirectly through the upstream part of the system.

One of the major issues in a hybrid system is the distribution of the permits. The permits of the emission sources regulated directly through tradable permits can be grandfathered. These firms will have to bear the costs of emission reductions and therefore political resistance against grandfathering will be low. The permits for the fossil fuel suppliers have to be auctioned since handing out for free to fuel suppliers without any real abatement effort in return will not be accepted politically.

A challenge connected with a hybrid system is to avoid double counting (Hargrave 2000). Fuels consumed by sources included in the trading program must be exempt from the indirect fuel tax that is put on the fuel price by the producers through the upstream system.

Basically the hybrid scheme is a compromise of upstream and downstream elements. In terms of advantages and disadvantages it chooses the political middle of the road of average political acceptability (lower than downstream and higher than upstream) and average administrative cost (lower than downstream, higher than upstream).

Mixed

In a mixed system, large polluters are regulated through a downstream tradable permit system, while other sources are regulated through some other instrument, such as performance standards or taxes. The advantages of such a system are that it gives an effective and efficient policy for large emitters. At the same time, it also includes small emitters, (Jepma et al. 1998). Furthermore, a high coverage of total carbon dioxide emissions is possible in such a system. The instrument that is most likely to be used to regulate the small emitters is a tax. Taxes are relatively easy to monitor, whereas the monitoring system needed for standards would be as high as in a downstream system. Hence, they would not give lower administrative costs.

The disadvantages of a mixed system stem mostly from the fact that two or more instruments are used simultaneously (see Hargrave 1998). First of all, it would bring high administrative costs because additional programs have to be set up besides the permits trading system. In our view this is a flawed argument. Administrative cost will be lower than in case of pure downstream permit trading. Second, if these other measures lead to other marginal costs of abatement in the other industries, inefficient allocation of emission control between sectors and carbon leakage may still take place. A third problem with other measures is that they do not guarantee that the countrywide emission ceiling is met.

Even though many problems are associated with a mixed system, it is the system preferred by the European Commission (COM 2000). Remarkably, the European Commission does not even mention other design options for emissions trading. The main reason why the European Commission prefers a mixed system is that in this way companies will be able to trade on a EU permit market, which in turn will give them the opportunity to prepare for international emissions trading. The problem of carbon leakage is dealt with in one sentence: "the potential competitive distortions caused by leaving out some sectors, or smaller sources within the covered sectors can be limited by ensuring that equivalent policies and measures are imposed on sectors and sources not covered by the trading system" (COM 2000, p. 13). Here the European Commission seems to think that it is easy to set 'equivalent policies and measures'. It is however not likely that an equal price can be created though other measures. Moreover, it will be impossible to adapt these measures as the price of permits changes over time.

Most of the authors mentioned above agree that the upstream design will outperform the other alternatives (Bohm 1999; Cramton and Kerr 1998; Festa 1998; Fischer et al. 1998; Jepma et al. 1998; Hargrave 1998, 2000). The reason for this is that an upstream design gives a high coverage of emissions and low administrative costs. Precisely on these points a downstream system performs badly. Even though a downstream system will have more parties participating in the permit market and might therefore be more efficient than an upstream system, it is assessed that this cannot outweigh the above-mentioned problems. There is also some support for a hybrid system, although the administrative costs for preventing double counting can be high. A mixed system is almost unanimously rejected (apart from the European Commission) because of the problems that arise when combining different instruments. There is however an alternative to the designs

Table 3.1: National permit trading schemes

	Downstream	Upstream	Alternative
Suppliers		Distribution Trade Monitoring	Monitoring
Distributors			$\Uparrow$
End-users	Distribution Trade Monitoring		Distribution Trade

discussed so far that the above-mentioned authors do not discuss.

Alternative design

In another strand of the literature on CO_2-emissions trading, an alternative design is mentioned, which combines elements from upstream and downstream systems (see Koutstaal 1993,1997, Zhang and Nentjes 1999; Duijse et al. 1998; Nentjes and Rietveld 2000). In this system, allowances are grandfathered to sources (big and small), as it would be in a downstream system, but compliance is monitored upstream at the level of producers and importers (see Table 3.1). The approach seeks to improve the political acceptability by extending grandfathering to small sources and avoid high administrative cost by concentrating monitoring of compliance on the few firms operating upstream.

Permits for large-scale fuel users could be grandfathered proportional to their carbon use in a reference year. Remind, this is the usual approach when quantity is rationed and quotas are distributed among firms. Grandfathering to small users can be done on a general basis: it is proportional to CO_2 emissions resulting from average fuel use per adult person in a reference year. In this way the administrative cost of establishing the fuel use of each single person, or household in a reference year is avoided. It can be expected that it will be politically more acceptable to grant permits for a basic good, such as fuel for consumer households, on an egalitarian base rather than proportional to past use.

The scheme requires that an end user who purchases fossil fuels 'pays' for the emissions by handing over emission permits to the fuel distributor. The distributor in turn can only buy fuels if he transfers the adequate number of permits to his supplier. In this way, the permits end up in the hands of producers and importers of fuel. They have to demonstrate, at the end of the year, that their sales of fuels (potential CO_2 emissions) are covered by an equivalent number of permits in their possession. The number of permits they actually can receive is restricted by the quantity of permits grandfathered to sources. The scheme is to a large extent self enforcing: the seller of fuels has an interest to receive the right number of permits from the purchaser. Since checking compliance is restricted to the relatively few upstream firms and the scheme is self-enforcing at the downstream levels the administrative costs of monitoring and enforcement are kept low.

The administrative cost of initial distribution and the transaction costs of permit transfer and of trade between downstream sources can be kept low by delegating implementation to a national agency and organizing the scheme in the form of carbon accounts and making permit transfer using pin card technology. All participants are registered at the national agency. End users receive in the beginning of the year their permits for that year on their account. The agency also sends them the carbon pin card. When purchasing fuels, for example after filling up at a petrol station, the end user uses his pin card to transfer an amount of permits (which corresponds with the carbon content of the acquired fuel) to the permit account which the distributor holds at the national permit agency. Transfer of carbon permits to the account of the gas and electricity distributor can be synchronized with paying the gas and electricity bill. Permit trade between end users can be facilitated by placing machines at strategic points where they can electronically increase or decrease their carbon account by buying or selling at the current carbon permit price. The machines are exploited by companies who trade professionally in carbon permits. The current market price arises from the transactions of and between the permit trading companies. At the end of the year the national agency establishes for every user unit the balance of the permit account. This is equal to: grandfathered permits (via chip card or account) plus the purchased permits minus the permits sold minus the permits used and transferred. This balance can be positive, but not negative. The positive balance is added to the permit account for the next year.

The implementation costs consist of the registration of the participants as well as the yearly allocation of permits and mailing of pin cards. We roughly estimate this to a few euros per participant. The costs of permit transfers between accounts will be comparable to the cost of money transfers between bank accounts. The monitoring focuses on the limited number of fuel importers and producers. Valued at a carbon price of 40 euro per ton of CO_2, a reasonable estimate of administrative cost is 1 percent of total carbon value (Nentjes and Rietveld 2000). The transaction costs of purchasing additional permits or selling excess permits will be not higher than two percent per transaction as we know from experience in the US.

The flexibility of the scheme arises from the possibility to trade permits freely; thus allowing firms and households to adjust the number of permits to their actual CO_2 emissions. Families living in small, well insulated apartments and without a car will end up with a permit surplus at the end of the year, which can either be sold or banked to cover emissions next year or later. This feature of grandfathering permits to all fuel users would increase the political support for the scheme compared to other designs. Simultaneously, the administrative cost, although they are higher than with an upstream system, are kept low, thus avoiding the major bottleneck of the pure downstream scheme.

One of the reasons why the administrative costs for the government are low in the alternative design are low is that they are transferred to the suppliers and distributors of fossil fuels. The idea behind it is that they administrate the flows of fossil fuels anyway and will thereby have lower costs of monitoring and control than would be the case with a separate agency. One disadvantage of the system is the large set up costs that are associated with it. At every place where fossil fuels can be bought, it must be possible to trade permits too. Hence, trading points have to be set up at every gas station. There is also some uncertainty about the level of the transaction costs in the system. Although the absolute costs per transaction will be low, the relative costs may be high. This will again apply especially to the transport sector. With every stop at the filling station, permits have to be transferred from the car owner/driver to the owner of the filling station. The number of permits transferred per transaction may be very low, but the time and costs per transaction are constant. How high the costs are is uncertain and should be determined before a final judgment can be made about the effectiveness of the system. Another possible disadvantage of the alternative scheme is that the population has to be acquainted with the system to lower resistance. It is likely that the system is seen as cumbersome and complex by the population, which would be the largest barrier to political acceptability of the scheme.

The alternative system presented here has as its major advantages that it is very efficient, and has relatively low monitoring and enforcement costs. The political acceptability of the scheme is enhanced by the possibility to grandfather all permits, but the public may perceive it as cumbersome and complex and may therefore resist it.

3.3.2 Credit Trading

Credit trading has originally been developed in the eighties in the US in the EPA emissions-trading program to introduce flexibility in a stringent scheme of direct regulation of emission standards for sources. The original spatial level for credit trading was the region, since it was developed for non-uniformly dispersing pollutants. In case of a national climate change policy based on performance standards, the credit-trading scheme could be implemented on a national scale. To our judgment the legal framework for such a type of national credit trading is already in place in the US and other countries could follow the example.

Credit trading is an instrument that cannot be used on its own but must always be combined with some other instrument that sets a baseline for emissions. The most commonly used instrument is some form of relative standard that does not place a cap on total emissions. Such relative standards can specify the allowed emissions per unit of output or per unit of some input. The allowed emissions per year are calculated by multiplying allowed CO_2 emissions per unit of output (input) by the level of output (input) that year. In this way, the emission baseline is determined ex post and need not be estimated beforehand. Although ex post estimation of the baseline may seem a large departure from the usual procedure, it does not differ so much from it in the end. Even when the baseline is estimated beforehand, the baseline is continuously adjusted as new developments arise. Hence, in the end, the baseline is the same, whether one estimates it beforehand and adjusts it, or whether one sets it ex post.

After the implementation of the relative standard, firms can start to trade credits. A firm can simply start selling credits whenever it expects that its total emissions will be below its baseline. At the end of the trading period, usually a year, all emission sources have to show that they are in compliance, i.e. that their actual emissions are below allowed emissions. Allowed emissions are here defined as the relative standard multiplied by the level of output plus the net purchased emission credits. If firms are not in compliance, they could be given a grace period in which they can purchase credits up to the level of their actual emissions as is the case in the US SO_x trading program.

It should be noted that with credit trading defined in this way, there is no need for explicit abatement projects to create credits. When a change in production leads to lower emissions per unit of output for example, the firm will stay below its baseline. This can hardly be defined as a project. However, the firm would receive credits for this. A consequence of this is that credit trading not necessarily leads to reductions in emissions at the seller. If the government sets the relative standard higher than the emissions per unit of output will be the firm can sell credits without reducing emissions. It is clear that this definition of credit trading diverges from the common descriptions of it. However, project based credit trading can be seen as a restricted version of the general credit trading design that we give here. Most of the experience with credit trading is with the project based kind. However, in the Netherlands, two general credit trading schemes are proposed. A recent proposal for NO_x emission trading (for all stationary sources lager than 20 MWth, about 200 firms) seeks to achieve the NO_x emission target of 55 kilo tonnes in 2010 by setting a performance standard of 50gr. NO_x emissions per GJ energy input in 2010. (Kamerstuk 26578 nr. 3, Vergaderjaar 2000-2001). Also for CO_2, an emissions trading scheme is discussed. This will be based on an energy efficiency standard set through negotiations with industry. Hence, in the NO_x trading scheme the basis is a relative input standard, while the basis for the CO_2 trading scheme is an output standard.

As will be clear, the above description of credit trading has much in common with permit trading with a cap. The only difference is the instrument that forms the basis of the trading system. With permit trading this is a ceiling on the total emissions of a firm. With credit trading, this is some relative standard that does not set an absolute ceiling on emissions, but a relative one; emissions are allowed to vary with output (or some input).

The disadvantages of credit trading can almost be characterized as the cardinal sins in economics: low effectiveness and low efficiency. The low effectiveness of the system is caused by the low effectiveness of the relative standards that are used as a basis for credit trading. Firms that enter the industry and expanding firms get a license to emit for free up to the level set by the relative standard. In case of unexpected rapid economic growth the emission target for the group of sources will be exceeded even though compliance at the firm level is perfect. In the proposed Dutch NO_x emissions trading scheme such a development should be signaled by an evaluation in 2006. If deemed necessary the performance standard will be made more stringent, but not sharper than 40 gr NO_x per GJ. This makes clear that the credit trading scheme requires more central planning and intervention than a cap and trade scheme without certainty that it will prevent too lax or too late adjustment of performance standards. In cap and trade schemes the whole problem is avoided by simply not allowing additional emissions for free once the allowed emissions have been distributed.

Next to effectiveness the efficiency of credit trading is to be criticized.

Just as permit trading, a credit trading system will improve cost efficiency for the trading firms as compared to no trading. Firms with low emission reduction costs will abate more than is necessary, and can sell credits to firms with high abatement costs. The result is that the marginal abatement costs of the trading firms will be more equal. However, a credit trading system will not be as efficient as permit trading. With credit trading there is an imbalance between emission reduction through a reduction in production and through other measures. More precisely, production is too high under credit trading based on performance standards, leading to higher marginal abatement costs (Ebert 1998, 1999 and Dijkstra 1999). The reason for this is that by regulating emissions through relative standards, firms cannot comply by reducing total emissions, but only by reducing emissions per unit of output or input. Hence, reducing emissions by reducing output will not give a better compliance. By regulating in such a manner, one efficient possibility of reducing emissions, reducing output, is excluded. It will be clear that this can never lead to the most efficient outcome.

Under relative standards, and thereby credit trading, firms that expand production receive additional emission allowances and firms that reduce production loose emission allowances. The same happens for firms that enter or exit the market. They respectively receive emission allowances for free or loose them on exit. Hence, a firm that wants to leave the market cannot sell its credits. Although this may lead to lower emissions if the other firms do not react by increasing production, it may also give an incentive for inefficient firms to stay in the market. With permit trading, firms with very low profitability would stop production and sell their permits since this will maximize profits. However, with credit trading, reducing output does not generate credits and therefore, firms with low profitability have no incentive to terminate production. In this way, a low cost option to reduce CO_2 emissions is foreclosed.

The major advantage of credit trading is that it has a high political acceptability (Boom and Svendsen 2000a,b and Boom 2001). Resistance from industry will be low since credit trading based on relative standards gives firms maximum flexibility. This system allows them to increase emissions with output and provides additional flexibility through the possibility of emissions trading. Furthermore, the emission allowances are distributed for free to the emission sources. Another important factor, especially to export oriented industry, is that the price of the goods produced in the regulated industries will be lower under credit trading than under permit trading. In this way, industry will have an advantage over foreign competitors regulated trough taxes or tradable permits. Precisely this aspect was clear in the failed proposals for CO_2 emissions trading in the Netherlands (CO2 Trading Commission 2002). Here the so-called sheltered sectors (those not facing foreign competition) will be regulated through an upstream system based on tradable permits, while the exposed sectors (those facing foreign competition) will be regulated through a credit trading system based on relative standards.

For all parties involved in designing and participating in the scheme, mainly politicians, civil servants and industry, credit trading has the advantage of familiarity. The basis of credit trading, relative standards, is well known to all groups. It is likely that the most preferred instrument is the one that deviates least from the existing policy (Lindblom 1959).

In many analyses, credit trading is associated with high transaction costs (UNCTAD 1998). Looking at the history of credit trading, this also seems to be vindicated by the practical experience with the instrument. However, in the design of credit trading outlined above, transaction costs will be as low as with permit trading. Transaction costs will be high when credit trading is based on abatement projects where the baseline is determined beforehand. In that case, the baseline has to be adjusted continuously and the project needs to be monitored constantly to ensure that the projected abatements level is realized. In the credit trading system described above, such projects are not necessary and neither is ex ante estimation of the baseline.

Another commonly held belief is that the preparation time for credit trading is long. Two points have to be taken into account here: the preparation time for setting up the program and the preparation time for individual trades. At least within Europe, permit trading is a radical break with the past in two ways. First of all, permit trading is based on ceilings on total emissions. This is not a very common way of designing environmental policy. More often, relative standards or taxes are used. With both these instruments, total emissions are allowed to increase when output increases. Hence, emission ceilings close the open access to emission space. On top of that, emissions trading is allowed, which also constitutes a break with the past. The process of putting both subjects on the political agenda for discussion and deciding to implement it will take time. With credit trading, the underlying instrument does not constitute a break with the past. Therefore, we expect that less time is needed to implement it. However, also credit trading constitutes a break with the past in that it allows for emissions trading. For both types of private emissions trading, making the necessary adjustments in legislation will be substantive and time consuming. Experience in the US with the development of credit trading in the 1980s and tradable permits in the 1990s and also the introduction of credit trading for NO_x in the Netherlands and CO_2 trading in the EU in the first years of the twenty first century has affirmed these predictions. If permit and credit trading are both based on sound national policies, and credit trading is designed in the way outlined above, there will not be a large difference in the transaction costs per individual trade. Therefore, we do not expect important differences in transaction cost in case of national schemes. In section 4 we shall discuss how far this also holds for international application of the flexibility mechanisms.

The upshot of the above discussion is that although performance standards complemented with credit trading are less effective and less efficient than cap and trade schemes they may meet less resistance from dominant interest groups, which makes the schemes politically more feasible.

3.4 International permit and credit trading

3.4.1 International permit trading

Article 17 of the Kyoto Protocol allows international emissions trading with a cap. Although the Protocol only talks of emissions trading between Parties, i.e. transactions between government of Annex B countries, there is wide consensus that it can include emissions trading with a cap between private parties (Bohm 1999; Hahn and Stavins 1999; Zhang and Nentjes 1999). International emission trading between private parties requires that caps have been established for participating firms. The caps on total emissions have to be set by national authorities and applied to the firms in their respective jurisdictions. Monitoring of firms' emissions, ownership of permits and their transfer, as well as enforcement are also tasks of national authorities in the first place. The requirements imply that international cap and trade schemes cannot work unless national cap and trade schemes have been established in the first place. They may comprise the whole economy or selected sectors or group of sources only. International emission trade basically is international linkage of national emission trading schemes. Once the unit of trade has been defined, eg one tonne of carbon, firms can trade internationally.

The national agencies to which the implementation of the national private trading scheme have been entrusted, should inform each other about transfrontier permit transactions. Suppose a Dutch firm buys permits from a firm in Denmark. The agency in Denmark registers the reduction of permits of the Danish firm and of course has the task to see to it that the Danish firm complies by not emitting more than its reduced number of permits allows. The Danish agency also registers that the international transaction has reduced the Assigned Amounts of Denmark. The Dutch agency registers the increase of the permit account of the firm in the Netherlands and the increase of Assigned amounts of the Netherlands. Coordination means here that the two agencies inform each other and check whether the number of permits sold in Denmark equals purchases in the Netherlands, to ensure consistency in the transfer of Assigned Amounts. Each agency is responsible for compliance with the after trade emission ceiling in its own country. Of course UNFCCC institutions set up for compliance monitoring also have to be informed in due time on the change in assigned amounts of countries, caused by international emission trading of private parties.

The alternative for international private party emission trading, conceived as internationally interlinked national cap and trade schemes, would be that national authorities define a cap for sectors or groups of firms and place them directly under the control of an international emissions authority which would have to work out and supervise the international emissions trading scheme. It is highly unlikely that national states would be willing to give up so much of their national sovereignty in the face of the possibility of linking national cap and trade schemes.

If it is accepted that national authorities enforce compliance of private parties engaged in national and international permit trade, this implies that the private seller of permits is liable in the case of non-compliance. If the seller's emissions exceed the reduced quantity of permits he possesses, the national authority has to apply sanctions. Introducing buyer liability for private parties means that the legislator in the buying country doubts the ability of the emission authority of the selling country to enforce the scheme and therefore needs the help of buyer liability. Buyer liability would make that the buyer has to assess the 'quality' of the permits he buys (will they be covered by genuine emission reductions or not).

The discussion on seller versus buyer liability that has been going on (see Yamin et al. 2001; Zhang 2000) is only relevant in so far as liability between Parties, i.e. national governments that have signed the Kyoto Protocol as Annex B Party, is at stake. Seller liability would be conform the system we have expounded in this chapter. Buyer liability seems to make sense if there are sound reasons to distrust the capability or willingness of some national authorities to enforce their national schemes properly. However, buyer liability would complicate the system of internationally linked national cap and trade schemes. A country that has been a buyer and sees its assigned amounts reduced, because it has purchased from a selling country that has not reduced its emissions sufficiently, is under the obligation to tighten the national cap. In case of grandfathering this would mean an unexpected reduction of permits for firms, thus creating an additional source of uncertainty for firms in the cap and trade scheme.

In our view a more appropriate approach to cope with the problem of inadequate monitoring and enforcement by some countries is to allow participation in international private party emission trading only for countries with certified international cap and trade schemes. The criterion used in certification should in particular specify the requirements of registering permit ownership, monitoring emissions, establishing compliance and application of sanctions (see Zhang and Nentjes 1999; Boom and Nentjes 2000). If a country fulfills these criteria, it is likely that it will comply with its commitment. One can imagine that under the supervision of the UNFCCC, the criteria are drafted and implemented much like the European Union drafted and applied its criteria for participation in the Euro-scheme. This solution presupposes that only the seller country is liable. Otherwise, setting up the criteria would have no meaning.

Since not all Annex B countries would meet the requirements for carbon permit trade an international system of linked national tradable permits schemes might initially start with only a handful of countries. Consequently, the 'full efficiency' of the scheme will only be achieved between the subset of participating countries. The Annex B countries not qualifying for participation in the emissions trading scheme, can still trade emissions trough joint implementation. A start with a small number of states does not preclude subsequent expansion to include other qualified countries according to the rules of procedure agreed before trading begins. Such an expansion will bring more emission sources into an international permit trading scheme and increase the scope for efficiency gains.

Although the requirements seem rather harsh, it should be noted that they are nothing more than the requirements for prudent national environmental policy. When a country does not satisfy these requirements it will not even be able to either monitor its domestic sources or to enforce environmental policy on them or both. Hence, in that case any domestic environmental policy will fail. In case of tradable permits the outcome would be disastrous.

3.4.2 International credit trading

Similar to cap and trade schemes international credit trading can be crafted upon national credit trading programs. National schemes are interlinked internationally by allowing credit trade with private parties in other Annex B countries with well-established national schemes of credit trading. We remind that national credit trading normally will be based on national performance standards, allowing limited, free emissions to entrants and expanding firms. Emission reduction credits are earned by emitting less than allowed emissions calculated by multiplying emission standards with the appropriate measure of capacity.

International credit trade is feasible and efficient if conditions are met similar to those relevant for international cap and trade: credits should be expressed in the same unit or different with fixed conversion factors, national agencies should register international credit transfer and inform each other and monitor and enforce compliance of the sources under their jurisdiction. Participation in the scheme would be reserved for countries with certified national credit schemes. The answer to the question on which issues international coordination or even harmonization is necessary are similar to those for the cap and trade program, although the controversy on auctioning versus grandfathering are avoided, since performance standards have always implied grandfathering.

Does the Kyoto Protocol allow international credit trading and if so which Article(s) does or do apply here? In our view article 17 of the Protocol does not apply exclusively to cap and trade schemes, but credit trading as well. The article defines the transfer of Parts of Assigned Amounts between Parties government, it does not say anything on how the underlying international exchange between private parties should be organized. It is clear that the article refers to emissions trading between Parties that have committed to an emission ceiling. However, nothing is said to suggest that private parties that trade should be placed under a cap too. The interpretation is that the Parties are responsible for meeting the emission ceilings and not the individual firms. It could be argued, and some authors have done so (Yamin et al. 2001; Hahn and Stavins 1999; Janssen 2001), that Joint Implementation is a type of baseline-and-credit trading. One might be tempted to go one step further and see international credit trade as an activity covered by Article 6 - the Joint Implementation article. At first sight it seems that despite the similarities between Joint Implementation and credit trading as specified in section 5.3.1 these are also major differences, making the application of article 6 to international credit trading less appropriate.

Article 6 specifically mentions that joint implementation should be based on investment projects that lead to emission reductions. Credit trading as defined above does however not fit this description. With joint implementation, a Party (a national government) can earn emission reduction units (allowing it to raise its emissions above its Kyoto emission commitment) by reducing emission below a baseline in a project carried out in the jurisdiction of another Party; the emission reduction units will lower the transferred emission ceiling of that other Party. The consensus is that Joint Implementation projects usually will be carried out by private parties in the donor and the host country. Article 6 states that approval of the project by the Parties is required. A plausible interpretation is that the emission reduction units or credits of a Joint Implementation project are calculated ex ante, even before the investment is carried out. They have the property of future (expected) emission reductions over the commitment years 2000 to 2012. Approval and certification of the emission reduction units is required ex ante. The Parties, that is the governments of the host and donor country should then ex ante agree on the emission reduction units to be transferred form the host country to the donor country.

In our design of international credit trade, the credits need not come from specific emissions reduction projects. If a reduction in production leads to lower emissions per unit of product, a lower demand of the product may lead to overcompliance by the firm. In that case, the firm could receive credits since it stayed below the relative standard. This would however hardly qualify as an emission reduction project. Furthermore, in our design trade in future emission reduction between private parties is possible, but only registration of the transfer is required. Future emission reduction units are transferred between the private parties and simultaneously between the Parties. Ex ante approval is not needed. Ex post, for example on an annual basis starting in 2008, compliance will be checked at the firm level: do actual emissions not exceed the allowed emissions that have been calculated on the base of the performance standard multiplied with output and transferred credits. When the enforcement regimes in both countries are adequate that legal entities in both countries will comply.

Another difference with joint implementation is that credit trading does not have to lead to genuine emission reductions. For example, the government could set the relative standard higher than the actual emissions per unit of output will be. In that way, the firm can receive credits for staying below the standard without having to reduce emissions. This also implies that credit trading does not necessarily exclude trading in hot air. Only if trading is explicitly based on projects where the baseline is defined on expected emissions, the permits or credits will always be backed by genuine emission reductions. In all other cases, this will not have to be so.

A further question is whether and how schemes of private party emission trading with a cap (nationally and internationally) can be combined with private party credit trading on an international scale. How do the two schemes interact and what are the consequences for effectiveness and efficiency? (see also Nentjes and Rietveld 2000, pp. 183-185)). Some countries may want to implement the two schemes for different sectors, as is the case in the Netherlands. It is even more likely to meet such a combination at the international level. As will be shown in chapters 6 and 7, countries may have a preference for one of the trading schemes depending on the trade balance in the goods market and on the difference between domestic and international price of credits and permits (see also Ulph 1996b; Dijkstra 1998). Some countries will therefore implement a credit trading system, while others will implement a permit trading system. A discussion of all the economic implications of continuing credit trade and permit trade requires a separate analysis and we shall therefore not pursue that line of research here.

3.5 Conclusions

In this chapter, three international emissions trading schemes have been presented: government trading, permit trading and credit trading. The main difference between government trading on the one hand and permit and credit trading on the other hand is that in the latter two schemes the traders are private parties, while in the first one, governments trade.

Government trading will enhance efficiency, although the small number of possible traders this scheme imply that the market is likely to be thin. The result is an inefficient market where market power and strategic behavior may be detrimental effects. On the positive side, government trading does not restrict the choice of national policy instrument. Furthermore, it gives governments greater control over trading, making it possible to ban trade with countries without a good compliance or with countries possessing hot air.

In this chapter, we have presented blueprints for two international emissions trading schemes between private parties. Both schemes have in common that a well functioning international flexibility mechanism requires implementation of a well defined and enforced national schemes: national cap and trade, respectively performance standards complemented with credit trading. On this basis, IET can be organized as internationally linked national schemes with seller liability between private parties and between Parties for assigned amounts. A well functioning, transparent permit market, respectively credit market with low transaction costs and low administrative costs can develop. Internationally linked, well designed national schemes of permit trading with a cap, respectively credit trading both create flexibility nationally and internationally for carbon users and tend to equalize the marginal cost of CO_2 emission control: a basic tenet of technical efficiency.

The efficiency of permit trading is highly dependent on the design of the domestic schemes of tradable permits. Although a large part of the literature points to an upstream scheme as the best design, such a design implies auctioning of permits, which decreases its political feasibility. An alternative is possible that will potentially perform better. In this alternative design all sources receive for free tradable permits, but the monitoring is done at the level of the suppliers of fossil fuels. In this way, high efficiency is combined with low administrative costs and relatively high political acceptability.

The crucial difference between cap and trade and performance standards with credit trading schemes is how the entry to 'emission space' is organized. Where credit trading is an addition to performance based direct regulation or covenants, entering firms and expanding incumbent firms can obtain additional emissions for free and firms that terminate their business loose the license to emit. In permit trading with a cap this is not the case. This may make that there is more support from industry for credit trading than for permit cap and trade schemes. However, by giving up tradable permits with an emission ceiling as a national instrument, the government sacrifices its control of total emissions and the certainty of realizing the emission goals set in the Kyoto Protocol. Next to that, performance standard based credit trading does not put a price on residual emissions not exceeding the standard. It leads to inefficiently high energy intensive output, requiring inefficiently high emission abatement.

However, for various reasons, some government may prefer credit trading to permit trading. It is therefore likely that both schemes will be used and that they will be combined at the international level. Such a combination does however give several problems. One is caused by the fact that credit trading does not put a ceiling on emissions. This is already a problem at the national level, but may be aggravated at the international level. Furthermore, a combination of credit and permit trading will lead to inefficiencies.

Chapter 4

Permit Trading and Credit Trading: A Comparative Static Analysis with Perfect and Imperfect Competition

4.1 Introduction

In the economic literature, emissions trading is almost always equated with a system based on a ceiling or cap on total emissions. In such a scheme, the government agency determines a cap on total emissions and divides this into permits that are distributed in some way over the existing firms, after which the firms are allowed to trade the permits. A prime example of such a scheme is the US SO_2 trading scheme that started in 1995 (see Schmalensee et al. 1998). Also the EU greenhouse gas emissions allowances trading scheme, that started on January 1 2005 is a cap and trade system (DIR 2003/87/EC).

Even before cap and trade, or permit trading, schemes had started, another type of emissions trading had been developed in the US and formalized in the EPA emissions trading program. Leaving aside the details, the program boils down to a scheme of emissions standards made flexible by allowing trade in emission reduction credits. Firms which succeed to keep actual emissions below the level required by the emission standard get emission reduction credits. Firms buying those credits are allowed to emit more than the level defined by the emission standard. Emission standard is here defined as maximum emissions per unit of some input or output. Firms are then allowed to sell credits when they can stay below the emission ceiling defined as the standard times the amount of input or output. Just as with permit trading, firms are allowed to trade before the realization of emission reductions (see Boom and Nentjes 2003). The lead trading program in the US is one example of emissions trading based on relative standards (see Svendsen 1998b). In 1982, the US Environmental Protection Agency limited the lead content in gasoline to 1.1 grams per gallon and tightened the standard in following years to 0.1 grams in 1986. Refineries that remained below the standard could sell credits to other refineries. Another example is the Dutch NO_x emissions trading scheme that started on June 1, 2005 (Ministry of VROM 2004a,b). In this scheme, a difference is made between combustion installations and process installations. The former emit NO_x as a result of the combustion of fuels. The standard for these installations is based on the amount of NO_x per gigajoule (GJ) fuel used, decreasing from 65 gram/GJ in 2004 to 50 g/GJ in 2010. Hence, combustion installations are faced with a relative input standard. Process installations however are regulated through a relative output standard determined as allowed NO_x emissions per unit of output that is different for different processes. Again, firms that remain below the standard are allowed to sell credits. In the following, emissions trading based on a cap on emissions will be denoted by permit trading, while emissions trading based on relative output standards will be denoted as credit trading.

It is very well possible for permit and credit trading to be combined, both at the national and at the international level. The UK greenhouse gas emissions trading scheme already combines both systems (DETR 2001). Here, some sectors were initially regulated, either through emission ceilings or relative standards, while others were not regulated. The latter could voluntarily join a permit trading scheme that was initiated through an auction of subsidies for emission reduction proposals. Simultaneously, the already regulated sectors are allowed to trade credits under some restrictions. In the Netherlands, a CO_2 emissions trading scheme was proposed where the energy intensive exporting sectors were regulated though a credit trading scheme, while the remaining sectors were regulated through permit trading (CO2 Trading Commission 2002). The European Commission has chosen to apply a cap and trade system, so that a combination of permit and credit trading for greenhouse gases should not be possible within the EU after 2005. However, if non-EU countries start credit trading schemes and would be allowed to link them to the EU scheme, combined trading will still be possible.

Credit trading is based on relative standards and therefore shares many characteristics with the latter instrument. This is especially the case when the industry is homogeneous since then there will be no trade in emissions. The working of relative standards under perfect competition is discussed by Ebert (1998,1999) and Dijkstra (1999) (see also Helfand 1991). The conclusions from this literature are that relative standards lead to higher industry output and higher marginal abatement costs than emission ceilings and permit trading. Furthermore, Dijkstra (1999) shows that in the long run, production per firm is lower and the total number of firms is higher under relative standards than under permit trading.

Boom (2001) was the first to give credit trading some thought. His analysis shows that output will be larger under credit trading than under permit trading (see also Boom and Nentjes 2003). Fischer (2001) discusses several instruments, one of which is credit trading. Fischer shows that credit trading can be seen as a tax on emissions equal to the credit price combined with a subsidy per unit of output equal to the average value of emissions embodied in output (credit price times the relative standard times output). Because of this, output will be larger under credit trading than is optimal. Furthermore, if the relative standard is set such that the credit price is equal to the Pigouvian tax rate, total emissions will be higher than the social optimum amount. Hence, to achieve the socially optimal pollution level a stricter standard has to be set, resulting in a higher credit price. Fischer assumes constant marginal production costs, and is therefore not able to analyze the effects on industry structure. Gielen et al. (2002) discuss the two systems in the framework of perfect competition in the goods market and discuss the linkage of the two schemes. They also find that credit trading leads to lower product prices and higher marginal abatement costs than permit trading. They do give a long-run model of the problem, but do not analyze the effect of the two schemes on firm size and the number of firms in the industry. Kuik and Mulder (2004) analyze the effect of permit, credit and combined trading on the Dutch economy. Fischer (2003) discusses the effect of combining permit and credit trading. She concludes that such a combination always leads to higher total emissions. However, this conclusion is based on the assumption that governments will not set a stricter relative standard in the credit sector.

The aim of this chapter is to give an insight in the functioning of and the differences between emissions trading based on emission ceilings and trading based on relative standards and of the implications of combing the two schemes. To this end, a partial equilibrium model of a polluting industry is developed. Two types of market structure are considered: perfect competition and oligopoly. In both cases, the number of firms is endogenous in the long run. To make a comparison between the instruments possible, it is assumed throughout the chapter that the government has imposed a ceiling on total industry emissions.

As mentioned above, the existing literature has already given some insight in the differences between permit and credit trading. This chapter adds to the existing literature in several ways. First, it gives a more formal analysis of the impacts of the two schemes and analyzes the long-run impacts on industry structure. This enables us to present proofs of the different impacts of the two schemes. Second, the chapter gives a full analysis of the performance of the two schemes under imperfect competition. Ebert (1998) already gives a short analysis of some of the effects of relative standards under imperfect competition, but does not give a full analysis and does not compare credit trading with other instruments. Different from other studies on environmental policy under imperfect competition, entry and exit is endogenous in our model. As will become clear, modeling imperfect competition in this way will lead to rather different results compared to when one assumes that the number of firms is fixed. Another issue often ignored is that the number of firms is an integer, also under perfect competition. In the general model, we will ignore this integer constraint as well. One might conjecture that this is rather harmless, because the number of firms is very large (Dijkstra 1999, p. 91, fn 14). In the specific model, where the number of firms is an integer, we will examine the consequences of an integer constraint. Finally, we analyze the effects of combining permit and credit trading formally, showing that this may both decrease or increase welfare.

The analysis consists of two parts. In the next section, a partial equilibrium model is developed. Here, both the short-run and long-run consequences of the two types of emissions trading are discussed and the effects on firm and total production, abatement costs, numbers of firms in the industry and welfare are given. Furthermore, an analysis of combined trading is given in section 4.2.4. However, some issues remain unresolved in the general model. Therefore, and to illustrate the properties of the two schemes, a more specific model is developed in section 4.3. This model is used to generate some simulations that give further insight into the working of the two schemes. Finally, section 4.4 gives some conclusions.

4.2 A General Model

In this section, a general model of permit and credit trading is developed, which will be used to analyze the cases of perfect and imperfect competition. In all cases, it is assumed that the government wants to regulate the emissions E of a pollutant so that the total level does not exceed the limit L, where L is binding. The pollutant is emitted by an industry, consisting of $n > 1$ identical firms. Costs of production for a single firm are given by $C(q, E)$, where q gives the level of output. The properties of the cost function are $C_q > 0$, $C_{qq} \geq 0$, $C_{qE} \leq 0$, $C_E < 0$ and $C_{EE} \geq 0$. Inverse demand for the product is given by $p = p(Q)$, with $Q = \sum_{i=1}^{n} q_i$.

4.2.1 Perfect Competition

With perfect competition, the number of firms in the market is large and no single firm has an influence on the product or emissions quota price. In this section, we ignore the integer constraint on the number of firms. We will first analyze optimal firm behavior in the short run and then discuss the effects on the industry in the long run.

Short run. In the short run entry and exit do not take place. Therefore, the number of firms in the sector is given. Because of this, it is possible that firms will receive a profit, or incur losses in the short run.

With permit trading, each incumbent firm receives an initial amount of permits $\bar{E}$. The price of permits that arises in the market is denoted by R^p. The profit function of the firm is then given by

$$\pi = pq - C(q, E) - R^p(E - \bar{E})$$

The firm maximizes profits, which results in the following first order conditions

$$\frac{\partial \pi}{\partial q} = p - C_q = 0 \tag{4.1}$$

$$\frac{\partial \pi}{\partial E} = -C_E - R^p = 0 \tag{4.2}$$

The first condition says that marginal revenue, in this case price, should be equated with marginal costs of production. Since $C_{qE} < 0$, regulation gives an increase in production costs and therefore an increase in the product price. The profit-maximizing emission level is found by equating the marginal costs of emissions to the price of permits. Condition (4.2) ensures that marginal abatement costs are equalized between firms. Both conditions together ensure that emission are reduced to the total emission ceiling at lowest cost.

With credit trading, the scheme is not based on an absolute standard, but on a limit on emissions per unit of output. Let the relative standard be given by $\bar{e}$. Total allowable emissions for the firm is then $\bar{e}q$ plus or minus the number of credits bought or sold respectively. Under these conditions, profits for the firm are given by

$$\pi = pq - C(q, E) - R^c(E - \bar{e}q)$$

where R^c is the market price for credits. The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p - C_q + R^c \bar{e} = 0 \tag{4.3}$$

$$\frac{\partial \pi}{\partial E} = -C_E - R^c = 0 \tag{4.4}$$

These can be combined to give

$$p = C_q + \bar{e} C_E \tag{4.5}$$

Since (4.4) holds for all firms, marginal abatement costs will be equalized between firms. Hence, credit trading achieves an efficient distribution of the abatement burden across firms. However, as a comparison between (4.3) and (4.1) shows, the production levels under the two schemes will not be identical. With credit trading, the term $R^c\bar{e}$ makes that firms no longer equate marginal production costs to the price of the product, but to a lower level, indicating that in equilibrium total output will be higher and the product price lower under credit trading. The additional factor can be seen as an output subsidy (Fischer (2001)) since the firm is allowed to emit more when it produces more.

It is now possible to determine the difference in impact of the two schemes in the short run:

Proposition 14 *Under perfect competition and in the short run, and with equal total emissions, credit trading will lead to higher total and firm output ($Q^c > Q^p$, $q^c > q^p$) and to a higher emission quota price ($R^c > R^p$) than under permit trading. Firm emissions are identical under the two schemes*

Proof: In the short run, $n^c = n^p = n$. Since $L^c = L^p = L$, we have that $E^c = E^p$. Furthermore, from (4.1) and (4.5) it follows that $Q^c > Q^p$. This combined with $n^c = n^p = n$ gives $q^c > q^p$. The fact that $q^c > q^p$ combined with $E^c = E^p$ gives $R^c > R^p$ since $C_{Eq} < 0$. $\square$

Long Run In the long run, the number of firms is variable. Besides profit maximization, it is now required that firms remaining in the industry have zero profits.

For permit trading, this implies that the long-run conditions for a firm are

$$p = C_q \tag{4.6}$$

$$pq = C(q, E) + R^p E \tag{4.7}$$

$$-C_E = R^p \tag{4.8}$$

$$nE = L \tag{4.9}$$

Note that the permits $\bar{E}$ grandfathered to the firms do not appear in the conditions above. The reason is that the permits represent an opportunity cost to the firm. If the firm does not cover its opportunity costs of emission, it would be better off if it sold its permits and closed production.

The long-run conditions for credit trading are

$$p = C_q + \bar{e}C_E \tag{4.10}$$

$$pq = C(q, E) \tag{4.11}$$

$$-C_E = R^c \tag{4.12}$$

$$nE = L \tag{4.13}$$

The last condition together with the assumption that firms are identical implies that $E = \bar{e}q$. As a final condition for both schemes, the inverse demand function is given by

$$p = p(nq) \tag{4.14}$$

It is possible to compare the equilibria under the two schemes. For permit as well as credit trading, we find from (4.6) and (4.7), and (4.10) and (4.11) respectively, that under both schemes optimal production is determined by

$$C(q, E) = qC_q - RE \tag{4.15}$$

We can now show the following

Proposition 15 *Under perfect competition and in the long run and with equal total emissions, credit trading leads to higher industry output ($Q^c > Q^p$), higher emission quota price ($R^c > R^p$), lower firm output ($q^c < q^p$), lower firm emissions ($E^c < E^p$) and a higher number of firms in the industry ($n^c > n^p$) than under permit trading.*

Proof: We will first see that $p^c < p^p$. Suppose that $p^c > p^p$. Then

$$n^c q^c < n^p q^p \Leftrightarrow \frac{n^c q^c}{n^c E^c} < \frac{n^p q^p}{n^p E^p} \Rightarrow \frac{E^c}{q^c} > \frac{E^p}{q^p} \tag{4.16}$$

From (4.15) it follows that (q, E) follows the same path for the two schemes, but at a different speed. Furthermore, E/q must decline as L declines from a non-binding level to zero. So from (4.16) it follows that (E^p, q^p) is ahead of (E^c, q^c). Then from $dE/dL, dq/dL > 0$ (see appendix 4.A) it follows that $E^c > E^p$ and $q^c > q^p$. Furthermore, we find

$$\frac{C(q^c, E^c)}{q^c} < \frac{C(q^p, E^p)}{q^p} \quad \text{since} \quad p^c = \frac{C(q^c, E^c)}{q^c} \quad \text{and} \quad \frac{dp}{dL} < 0$$

But we had assumed

$$\frac{C(q^c, E^c)}{q^c} = p^c > p^p > \frac{C(q^p, E^p)}{q^p}$$

This shows that $p^c > p^p$ is impossible, so that we must have $p^c < p^p$.

This shows that $Q^c > Q^p$. It then follows that

$$\frac{L}{Q^c} < \frac{L}{Q^p} \quad \Leftrightarrow \quad \frac{n^c E^c}{n^c q^c} < \frac{n^p E^p}{n^p q^p} \quad \Leftrightarrow \quad \frac{E^c}{q^c} < \frac{E^p}{q^p} \tag{4.17}$$

Equation (4.15) implies that if $R^c = R^p$, output and emissions and hence E/q per firm are identical under the two schemes. Then from (4.17) and $dR/dL > 0$, it follows that $R^c > R^p$. From this and (4.15) it then follows that $E^c < E^p$ and $q^c < q^p$. Furthermore, from $Q^c > Q^p$ and $q^c < q^p$ it follows that $n^c > n^p$. $\square$

This shows that the long-run effects are rather different from the short-run effects. In the short run, output per firm is higher under credit trading than under permit trading, while emissions per firm are equal under the two schemes. In the long run, both output and emissions per firm are smaller under credit trading than under permit trading. On the other hand, an important similarity between the short and long run is that abatement costs per unit of output are higher under credit trading than under permit trading.

In appendix 4.A, the effect of a change in total emissions limit L on product price, output, emissions per firm and the number of firms is derived. With this, we can also analyze the effect of the introduction of regulation, where we assume that L changes from not binding to just being binding. As is shown in the Appendix, for both permit and credit trading we find $dq/dL > 0$, $dE/dL > 0$ and $dp/dL \leq 0$. The introduction of emissions trading, starting from a position without emission control policy, will result in a decrease in production per firm, a decrease in emissions per firm and an increase in the price of the product. The latter also implies that total output will be lower. For both schemes, it remains unclear whether the number of firms increases or decreases as a result of regulation. The outcome depends on the cost function and on the slope of the demand function. The steeper the demand curve, the more likely it is that the number of firms will increase as the limit on total emissions is set lower. When the demand curve is rather flat, one would expect a reduction in the number of firms. Hence, under both emissions trading schemes regulation could result in an increase or a decrease in the number of firms in the market.

4.2.2 Imperfect Competition

With imperfect competition, each firm has an influence on the market price of the product. We will assume Cournot competition between the competitors so that $p = p(Q)$, i.e., price is a function of total output and individual firms can affect the market price by changing their output.

The emission trading scheme is confined to the sector analyzed, which implies that firms should also have market power on the emissions quota market. In such a market, firms will bargain with each other over the price. The outcome is dependent on the market power of the individual firms and the initial distribution of emission quotas over the participants in the quota market. A complicating factor is that incumbent firms may form a cartel, refusing to sell emission quotas to new entrants, thereby effectively deterring entry if emissions are necessary for production. The existence of an effective competition authority could prevent such behavior, however. In order not to complicate the analysis more than necessary and to keep focus on the main issue of the chapter, it is assumed that firms cannot effectively deter entry. Furthermore, it is assumed that the outcome of bargaining between firms is the perfectly competitive emission quota price.

Short run. With imperfect competition and permit trading, the profit function for a firm becomes

$$\pi = p(Q)q - C(q, E) - R^p(E - \bar{E})$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p'q + p - C_q = 0 \tag{4.18}$$

$$\frac{\partial \pi}{\partial E} = -C_E - R^p = 0 \tag{4.19}$$

So, the firm should equate marginal revenue with marginal production costs and marginal costs of abatement with the price of permits.

When regulation takes the form of credit trading, the profit function becomes

$$\pi = p(Q)q - C(q, E) - R^c(E - \bar{e}q)$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p'q + p - C_q + R^c\bar{e} = 0 \qquad (4.20)$$

$$\frac{\partial \pi}{\partial E} = -C_E - R^c = 0 \qquad (4.21)$$

It is clear that the short-run first order conditions for imperfect competition closely resemble those for perfect competition. The only difference is that under imperfect competition firms take the effect of changes in their own output on the price of the product into account.

This gives the following result:

Proposition 16 *Under imperfect competition and in the short run, credit trading will lead higher total and firm output ($Q^c > Q^p$, $q^c > q^p$) and to a higher emission quota price ($R^c > R^p$) than under permit trading. Firm emissions are identical under the two schemes ($E^c = E^p$).*

Proof: See Proof of Proposition 14.□

Hence, the short-run effects of the two schemes under imperfect competition are basically the same as under perfect competition.

Long Run. In the long run the number of firms can vary through entry and exit. More precisely, the equilibrium number of firms will be such that if one more firm entered the market all firms would make a loss. That is, n^* is the equilibrium number of firms for which it holds that

$$\pi(n^*) \geq 0, \quad \text{and} \quad \pi(n^* + 1) < 0 \qquad (4.22)$$

Note that we can state these conditions in this way because we have assumed that all firms are identical.

With permit trading, the long run profit function becomes

$$\pi = p(Q)q - C(q,E) - R^p E \tag{4.23}$$

The long-run conditions for permit trading with imperfect competition are then

$$\begin{aligned} p'q + p &= C_q \\ p(Q)q &\geq C(q,E) + R^p E \\ -C_E &= R^p \\ nE &= L \end{aligned}$$

and (4.22). The slope of the reaction function is found by total differentiation of (4.18) and rearranging:

$$-1 < \frac{dq_i}{dQ_{-i}} = -\frac{qp'' + p'}{qp'' + 2p' - C_{qq}} < 0 \tag{4.24}$$

where $Q_{-i} = \sum_{j=1,j\neq i}^{n} q_j$. The denominator is negative by the second order condition (see appendix 4.B), and so we need the numerator to be negative as well to assure that the Nash equilibrium is stable. In the following we shall assume that this is the case. In fact, we shall assume that the stricter condition:

$$nqp'' + 2p' < 0 \tag{4.25}$$

is satisfied. This also guarantees that the denominator on the RHS of (4.24) is negative.

With credit trading, the firm knows that its actions will have an influence on the standard set. Specifically, when a firm increases its output, total industry output increases and therefore the government will set a stricter standard in order to keep industry emissions constant. Recall from above that the standard is $\bar{e} = \frac{L}{Q}$. The profit function with credit trading can then be rewritten as

$$\pi = p(Q)q - C(q,E) - R^c\left(E - \frac{L}{Q}q\right)$$

The long-run conditions for profit maximization then become

$$p'q + p = C_q - R^c \left(\frac{n-1}{n} \frac{E}{q} \right) \tag{4.26}$$

$$p(Q)q \geq C(q, E)$$

$$-C_E = R^c$$

$$nE = L$$

and (4.22). From a comparison of (4.26) with (4.20), it is clear that in the long run, firms have less incentive to expand production since they know that a change in output will have an influence on the relative standard set. With monopoly $Q = q$, and (4.26) becomes $p'q + p = C_q$. That means that a monopolist is perfectly aware that as it changes its output, the change in the standard will be equivalent. Hence, in this case, there is no difference between a credit and a permit trading scheme, or for that matter, regulation through an absolute or relative standard. In general then, the lower the number of firms in the market, the more closely the outcomes under credit and permit trading resemble each other.

The slope of the reaction function is found from (4.26):

$$-1 < \frac{dq_i}{dQ_{-i}} = -\frac{nq(qp'' + p') + C_E \left(\frac{n-1}{n}\right) \frac{E}{q}}{nq(qp'' + 2p' - C_{qq}) + C_E \left(\frac{n-1}{n}\right) \frac{E}{q}} < 0$$

The denominator and numerator are negative by (4.25), so that the Nash equilibrium is stable.

For the relative impact of the two schemes in the long run we find

Proposition 17 *In the long run under imperfect competition, the number of firms under credit trading will be equal or larger than under permit trading ($n^c \geq n^p$). Then,*

1. *If $n^c = n^p$, credit trading will lead to higher total and firm output ($Q^c > Q^p$, $q^c > q^p$) identical firm emissions ($E^c = E^p$) and to a higher emission quota price ($R^c > R^p$) than under permit trading.*

2. *If $n^c > n^p$, credit trading leads to higher total output ($Q^c > Q^p$) and lower firm emissions ($E^c < E^p$).*

Proof: Assume that $n^c = n^p$. From the profit functions and (4.18) and (4.20) it then follows that under both permit and credit trading profits can be written as

$$\pi = qC_q + EC_E - p'q^2 - C(q, E)$$

Differentiating partially with respect to q yields:

$$\frac{\partial \pi}{\partial q} = qC_{qq} + EC_{qE} - q(2p' + nqp'') > 0$$

The inequality follows from (4.25) and (4.61). Since $q^c > q^p$ from (4.18) and (4.26) when $n^c = n^p$, it also follows that $\pi^c > \pi^p$ when $n^c = n^p$. This shows that there is a greater possibility for entry under credit trading than under permit trading and hence, that $n^c \geq n^p$. In Part 1), since $n^c = n^p$ and $L^c = L^p$, it follows that $E^c = E^p$. Furthermore, as we have seen above, it is clear that $Q^c > Q^p$. This combined with $n^c = n^p$ gives $q^c > q^p$. The fact that $q^c > q^p$ combined with $E^c = E^p$ gives $R^c > R^p$ since $C_{Eq} < 0$. In Part 2), $Q^c > Q^p$ follows from $dp/dn < 0$ (see appendix 4.B). $E^c < E^p$ follows immediately from $n^c > n^p$ and $L^c = L^p$. $\square$

Unfortunately, it is not possible to determine the relationship between q^c and q^p and that between R^c and R^p for $n^c > n^p$. As is clear from the analysis in appendix 4.B, for both schemes, q decreases as the number of firms increases. However it is not clear whether q^c is larger or smaller than q^p. For the emission quota price, the result of an increase in the number of firms is ambiguous. Therefore, we cannot say whether the credit price will be larger or smaller than the permit price.

For a fixed number of firms, we can determine what the effect of a change in L is on most other variables and thereby the effect of introducing regulation. In appendix 4.B, it is shown that $dq/dE > 0$, $dp/dE < 0$ for both schemes, and $dR^p/dE^p < 0$ for permit trading. For credit trading, the expression for dR^c/dE^c is ambiguous. However, when regulation goes from

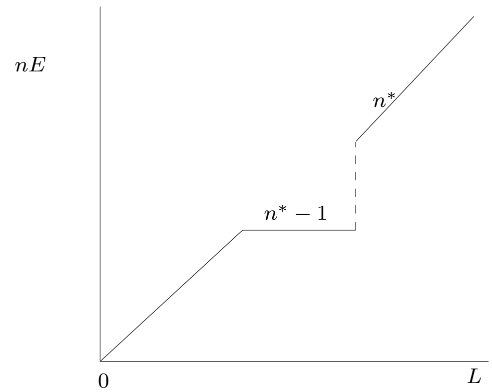


Figure 4.1: Some L not obtainable with PT

non-binding to binding, $dR^c/dE^c < 0$. So the introduction of emission trading, starting from a position without regulation, will always lead to lower firm and total output and to higher marginal abatement costs. When entry or exit takes place we cannot analyze the effect of a change in L because the number of firms changes discretely which will have a large effect on the change in the other variables.

We have assumed in this chapter that the goal of environmental policy is to achieve a certain level of emissions L, lower than the unconstrained emission level. The question is however, whether environmental policy always can achieve the emission limit set.

Proposition 18 *In a permit trading scheme, let L decrease from the non-binding level to zero. Then if n^p decreases, some L may not be attainable.*

Under permit trading, lowering the emissions limit may lead to the exit of a firm. It may then be that the unconstrained emission level of the remaining firms is lower than the emission limit. The result is that for some L, actual emissions will be lower than the limit. This is illustrated in Figure 1. An example of this is given in Section 4.3.2.

Proposition 19 *In a credit trading scheme, let $\bar{e}$ decrease from the non-binding level to zero. Then*

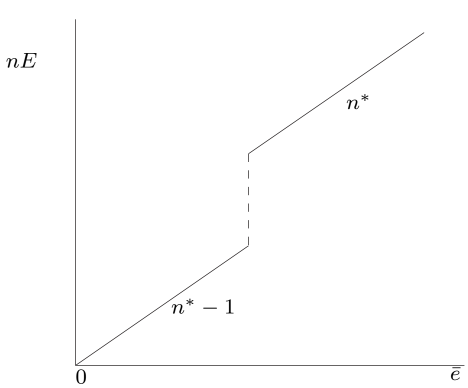


Figure 4.2: Some L not obtainable with CT

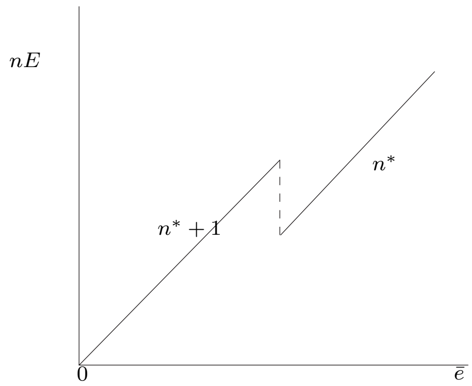


Figure 4.3: Some L obtainable with different $\bar{e}$

i) If n^c decreases, some L cannot be realized.

ii) If n^c increases, some L can be realized with different $\bar{e}$.

Proof: i) If $\bar{e}$ remains the same, and n^c decreases, it is shown in appendix 4.B that total output decreases as well. Since $\sum_{i=1}^{n} E_i = \bar{e}Q$, it follows that total emissions also decrease discretely. It then follows that certain L cannot be realized. ii) If at fixed $\bar{e}$ the number of firms increases, total output increases (see appendix 4.B) and thereby total emissions. Hence, at the $\bar{e}$ where n^c increases, total emissions increase, whereafter they decrease as $\bar{e}$ decreases. It then follows that certain L can be obtained with different $\bar{e}$ and n^c.$\square$

This shows that under credit trading the government cannot reach certain L when the number of firms decreases. The reason is that a decrease in the number of firms will also lead to a decrease in total output. Since under credit trading total emissions are given by total output times the relative standard, it follows that total emissions will decrease as well and in a discrete manner. The result is that actual emissions will be lower than the total emission limit that the standard aimed to achieve. This is shown in Figure 4.2. If on the the other hand the number of firms increases when the standard is tightened, the government can reach the same emission level with different standards and different numbers of firms. This is illustrated in Figure 4.3. Basically the reverse happens compared with when the number of firms decreases. At the standard where an additional firm enters the market, total output, and thereby total emissions will increase. Then as the relative standard is lowered even further, emissions fall again. If the government is aware of this fact, it should choose the standard that gives highest welfare. This clearly is the standard that gives the highest number of firms and thereby the highest output.

We will see examples of both parts of Proposition 19 in Section 4.3.2.

4.2.3 Welfare

The emission trading schemes described above will have different impacts on welfare. To compare the performance of the two instruments, we assume that they are set such as to give the same amount of total emissions L. Here, welfare is given by consumer plus producer surplus. This is given by the area under the demand function minus production costs. The problem now is to maximize

$$W = \int_0^{nq} p(Y)dY - nC(q, E) - \lambda(nE - L) \tag{4.27}$$

In the short run, only production is variable, while the number of firms, n, and the total ceiling on emissions, L, are fixed. The latter two imply that E and λ are fixed. Maximizing (4.27) with respect to q gives as the short run first order condition

$$p = C_q$$

In the long-run, all variables can change. Therefore, to find the optimum, we must maximize (4.27) with respect to q, n, E, and λ, which gives

$$\begin{aligned} p &= C_q \\ pq &= C(q, E) - \lambda E \\ -C_E &= \lambda \\ nE &= L \end{aligned} \tag{4.28}$$

This enables us to state the following for perfect competition:

Proposition 20 *Under perfect competition, only permit trading leads to optimal welfare, while credit trading leads to lower welfare.*

Proof: Comparing (4.28) with (4.6)-(4.9) and (4.10)-(4.13), it follows immediately that permit trading fulfills all optimality conditions for welfare while credit trading does not. □

This result may seem somewhat odd since credit trading leads to higher output and thereby to a larger consumers' surplus. Since profits are zero under both instruments, one might derive from this that credit trading would lead to higher welfare. There are however two other effects that have to be taken into account. First, costs of production are higher under credit trading. Credit trading is an inefficient instrument because it limits the options for reducing emissions. One effective way to reduce emissions is by reducing output. However, under credit trading, this option will not be utilized to its maximum because reducing output also reduces the total allowable amount of emissions for the firm. Second, under permit trading, the firm has to cover the opportunity cost of its emissions, which is not the case under credit trading. This is a cost to the firm, but it is a resource rent reaped by the shareholders. Under credit trading, the resource rent is competed away.

With imperfect competition, it is not immediately clear which instrument leads to highest welfare. There are three effects that have to be taken into account. In general, imperfect competition leads to lower than optimal production. As we have seen above, credit trading leads to higher output than permit trading and therefore seems to have an advantage. Credit trading also results in more (at least not less) firms in the sector. This means that under credit trading firms have less market power, which again leads to a higher output level than under permit trading. However, credit trading also leads to higher abatement costs than permit trading. The overall effect depends on the size of the three effects.

4.2.4 Combining Permit and Credit Trading

When permit and credit trading are combined, emission quotas will flow from the sector with the lowest to the sector with the highest quota price. We will only discuss the case where the two sectors are identical in every respect, except that they operate on two different markets (with identical demand functions) and that one sector is regulated through permit trading while the other is regulated through credit trading. As was shown above, under perfect competition and under imperfect competition with $n^c = n^p$, the credit price is always higher than the permit price and permits will flow to the credit sector. However, with imperfect competition and $n^c > n^p$, this need not be the case so that here credits may flow to the permit sector. The effect will be that the sector selling emission quotas will reduce production and the product price will increase. The buying sector will expand production and the product price in this sector will fall. Thus combined trading stimulates output of the sector which initially had the highest emission quota price at the expense of output of the other sector.

Proposition 21 *Assume two perfectly competitive industries that are identical in every respect, but produce two different products. One industry is regulated through permit trading and the other through credit trading. Allowing emissions trading between the two sectors will lead to identical emissions quota price ($R^c = R^p = R$), the permit sector selling quotas to the credit sector, and*

1. *in the short run, to a decrease in output per firm and an increase in product price in the permit sector. In the credit sector, firm output will increase and product price will decrease. Furthermore, it will lead to higher firm emissions and output ($E^c > E^p$ and $q^c > q^p$) and lower product price ($p^c < p^p$) in the credit sector than in the permit sector.*

2. *in the long run to a decrease in output and emissions per firm and an increase in the product price in the permit sector. In the credit sector, the product price will decrease, while firm emissions and output may increase or decrease. In both sectors, the number of firms may increase*

or decrease. Furthermore, combined trading will lead to identical firm emissions ($E^c = E^p$), identical firm output ($q^c = q^p$), a higher number of firms ($n^c > n^p$), and a lower product price ($p^c < p^p$) in the credit sector than in the permit sector.

Proof. Combining the two schemes will give $R^c = R^p = R$ since the quota market is defined as perfectly competitive. Since $R^c > R^p$ in the short run (Proposition 14) as well as in the long run (Proposition 15), the quota price will decrease for the credit sector and increase for the permit sector. As a result, the permit sector sells quotas to the credit sector. Then

1. In the short run, combining the schemes leads to a decrease in E^p and an increase in E^c. In appendix 4.A, it is shown that $dq^p/dE^p > 0$, $dp^p/dE^p < 0$, $dq^c/dE^c > 0$ and $dp^c/dE^c < 0$. Thus, combined trading results in a decrease in q^p and p^c and an increase in p^p and q^c. Since separate schemes already feature $q^c > q^p$ and $p^c < p^p$, the same inequalities hold for combined trading.

2. In the long run, combining the schemes leads to a decrease in L^p and an increase in L^c. In appendix 4.A, it is shown that $dq^p/dL > 0$, $dE^p/dL > 0$, $dp^p/dL < 0$ and $dp^c/dL < 0$ while the signs of dn^p/dL, dq^c/dL, dE^c/dL and dn^c/dL are ambiguous. From (4.15) it follows that q and E follow the same path with permit and credit trading. Combined with $R^c = R^p = R$, this means that $E^c = E^P$ and $q^c = q^P$. From (4.6) and (4.10) we find that $p^c < p^p$. Combining this with $q^c = q^p$, it is clear that $n^c > n^p$ must hold. □

With imperfect competition and $n^c > n^p$, we could not state whether the credit price was higher or lower than the permit price. Therefore, for imperfect competition, we can only state a result for the case where $n^c = n^p$:

Proposition 22 *Assume two imperfectly competitive industries that are identical in every respect, but produce two different products. One industry is regulated through permit trading and the other through credit trading.*

Assume furthermore that the outcome in the emissions quota market is the perfectly competitive quota price so that $R^c = R^p = R$. Then, under combined trading, in the short run and in the long run with $n^c = n^p$, the permit sector sells quotas to the credit sector, resulting in $E^c > E^p$. In the permit sector firm output will decrease and product price will decrease, while in the credit sector, firm output will increase and product price will decrease. Furthermore, we find that $E^c > E^p$, $q^c > q^p$ and $p^c < p^p$.

Proof: With $n^c = n^p$ under separate schemes, $R^c > R^P$ (Propositions 16 and 17). Combined trading then leads to an increase in E^c and a decrease in E^p. As is shown in appendix 4.B, for both the short and long run, $dq/dE > 0$ and $dp/dE < 0$ for both schemes. Since with separate schemes we had $q^c > q^p$ and $p^c < p^p$, the result follows immediately. $\Box$

Welfare

It follows directly from the analysis of Section 4.2.3 on welfare that a system where one sector is regulated through permit trading and the other through credit trading is not welfare maximizing. However, this does not immediately show what happens to welfare when a permit and credit sector are allowed to trade. This is shown formally below, both for the short and the long run for perfect competition and for the case where $n^c = n^p$ under imperfect competition.

The effect of combining the two schemes on total welfare can be analyzed by determining the change in welfare as a result of a change in the division of the emission ceiling over the two sectors.

Welfare is given by

$$W = \int_0^{Q^c} p^c(Q^c)dQ^c - n^c C^c(q^c, E^c) + \int_0^{Q^p} p^p(Q^p)dQ^p - n^p C^p(q^p, E^p)$$

With the total emission limit given by

$$n^c E^c + n^p E^p = L^c + L^p = S \tag{4.29}$$

In the short run, the number of firms is fixed, so we find

$$\frac{dE^p}{dE^c} = -\frac{n^c}{n^p} \tag{4.30}$$

Combined trading leads to an increase in E^c. Differentiating welfare with respect to E^c, while holding n^c and n^p constant, and using (4.30) gives for the short run

$$\begin{aligned}\frac{dW}{dE^c} =& n^c p^c \frac{dq^c}{dE^c} - n^c C_{q^c} \frac{dq^c}{dE^c} - n^c C_{E^c} \\ & - n^c p^p \frac{dq^p}{dE^p} + n^c C_{q^p} \frac{dq^p}{dE^p} + n^c C_{E^p}\end{aligned} \tag{4.31}$$

In the long run, the number of firms can change, and from (4.29) we find that $dL^p/dL^c = -1$. The change in welfare is then given by

$$\begin{aligned}\frac{dW}{dL^c} &= q^c p^c \frac{dn^c}{dL^c} + n^c p^c \frac{dq^c}{dL^c} - C^c(q^c, E^c)\frac{dn^c}{dL^c} - n^c C_{q^c}\frac{dq^c}{dL^c} - n^c C_{E^c}\frac{dE^c}{dL^c} \\ & - q^p p^p \frac{dn^p}{dL^p} - n^p p^p \frac{dq^p}{dL^p} + C^p(q^p, E^p)\frac{dn^p}{dL^p} + n^p C_{q^p}\frac{dq^p}{dL^p} + n^p C_{E^p}\frac{dE^p}{dL^p}\end{aligned} \tag{4.32}$$

Perfect Competition For the case of perfect competition, (4.31) can be simplified by using (4.1) and (4.5) to

$$\frac{dW}{dE^c} = n^c \left[C_{E^c} \left(\frac{E^c}{q^c} \frac{dq^c}{dE^c} - 1 \right) + C_{E^p} \right] \tag{4.33}$$

For the long run, (4.32) can be rewritten using (4.6), (4.7), (4.10) and (4.11) and noting that $E^c = \bar{e} q^c$ and that $E\frac{dn}{dL} + n\frac{dE}{dL} = 1$ for both sectors. We find

$$\frac{dW}{dL^c} = n^c C_{E^c} \left(\frac{E^c}{q^c} \frac{dq^c}{dL^c} - \frac{dE^c}{dL^c} \right) + C_{E^p} \tag{4.34}$$

This allows us to state the following

Proposition 23 *Assume two identical perfectly competitive industries that produce a different product, with one industry regulated through permit trad-*

ing and the other through credit trading. In this situation, combining the emissions trading schemes may lead to a welfare increase both in the short and in the long run. However, full combined trading is never optimal.

Proof: Monotonicity requires that emissions per firm must decrease with the strictness of the relative standard (Dijkstra, 1999, p. 80). This implies

$$\frac{d(E/q)}{dE} = \frac{1 - \frac{E}{q}\frac{dq}{dE}}{q} \geq 0 \tag{4.35}$$

This shows that $0 < \frac{E^c}{q^c}\frac{dq^c}{dE^c} < 1$. For the separate schemes it holds that $C_{E^c} < C_{E^p} < 0$. Hence, the first term on the RHS of (4.33) is positive, while the second term is negative and for perfect competition dW/dE^c may be positive or negative. This implies that combining the two schemes can lead to an increase in welfare. Note however that when there is full trading, $C_{E^p} = C_{E^c}$ and (4.33) becomes negative. Hence full trading is not optimal, but welfare under full trading may be higher under full combined trading than under separate schemes.

For the long run, it is shown in appendix 4.A.2. that

$$-\frac{1}{n} < \frac{E^c}{q^c}\frac{dq^c}{dL^c} - \frac{dE^c}{dL^c} < 0$$

It then follows that the sign of (4.34) can be positive or negative. Again here, when there is full combined trading, $C_{E^p} = C_{E^c}$ and (4.34) becomes negative. $\square$

With perfect competition there are two effects. First, abatement costs increase in the permit sector and decrease in the credit sector ($C_{E^p} - C_{E^c}$). Since initially marginal abatement costs are higher in the credit sector than in the permit sector, this effect leads to a welfare increase. Second, production increases in the credit sector and decreases in the permit sector. In itself, the production change in the permit sector is not distortionary, because output is optimal, given total emissions. In the credit sector, however, output is larger than optimal, and the gap between actual and optimal output increases when the two sectors are combined. This effect is given by $(C_{E^c}\frac{E^c}{q^c}\frac{dq^c}{dE^c})$ and causes a decrease in welfare. The total effect on welfare then depends on the size of these two effects. If marginal abatement costs are much higher in the credit sector, while the output effect is not very large, combining the two schemes may lead to an increase in welfare compared to leaving the two schemes separate.

Imperfect Competition For the case of imperfect competition, (4.31) can be rewritten, using (4.18) and (4.20), to find

$$\frac{dW}{dE^c} = n^c \left[C_{E^c}\left(\frac{E^c}{q^c}\frac{dq^c}{dE^c} - 1\right) - p^{c\prime}q^c\frac{dq^c}{dE^c} + C_{E^p} + p^{p\prime}q^p\frac{dq^p}{dE^p}\right] \tag{4.36}$$

We then find the following

Proposition 24 *Assume two identical imperfectly competitive industries that produce a different product, with one industry regulated through permit trading and the other through credit trading. In this situation, combining the emissions trading schemes may lead to a welfare increase in the short run.*

Proof: For imperfect competition, the terms $p^{c\prime}q^c\frac{dq^c}{dE^c}$ and $p^{p\prime}q^p\frac{dq^p}{dE^p}$ are both negative. Furthermore, (4.35) still holds. Hence, also (4.36) is ambiguous and for imperfect competition dW/dE may be positive or negative. □

With imperfect competition there are again two effects. The first effect is the same as with perfect competition. That is, abatement costs increase in the permit sector and decrease in the credit sector as a result of the transfer of permits to the credit sector. The second effect is the output effect. Production in the credit sector increases, while it decreases in the permit sector. This leads to a certain loss in the permit sector equal to $n^c p^{p\prime}q^p\frac{dq^p}{dE^p}$. However, in the credit sector, the effect is equal to $n^c\left(C_{E^c}\frac{E^c}{q^c} - p^{c\prime}q^c\right)\frac{dq^c}{dE^c}$, which may be positive or negative. The factor $n^c C_{E^c}\frac{E^c}{q^c}\frac{dq^c}{dE^c}$ leads to a loss in welfare because credit trading leads to a distortion in the production level. However, the increase in production also leads to a higher consumers surplus (given by $n^c p^{c\prime} q^c \frac{dq^c}{dE^c}$), which leads to higher total welfare. Hence under imperfect competition, an increase in welfare is more likely when the distortionary effect of credit trading is small and $p^{c\prime} < p^{p\prime}$ and $\frac{dq^c}{dE^c} > \frac{dq^p}{dE^p}$. That is, combining the two schemes is more likely to lead to an increase in welfare when the inverse demand function is concave and output in the credit sector increases more than it decreases in the permit sector.

For imperfect competition, we cannot show the long-run effect of combining the two schemes on welfare when $n^c > n^p$. The problem is that it is hard to determine when entry or exit will take place and a change in the number of firms will have a large impact on the results.

4.3 Simulation

The analysis above leaves many questions open. Under perfect competition, the effects of combined trading on the number of firms and welfare are still not fully clear. Moreover, the size of the effects discussed above is unknown. Recall also that in the analysis above we ignored that the number of firms under perfect competition is an integer. This may affect the outcomes and should be investigated. In the simulation model given below, the number of firms is an integer, both under perfect and imperfect competition. Furthermore, the outcome under imperfect competition is not entirely clear, especially in the long run when $n^c > n^p$. To analyze these problems, we will deploy a more specific model. Numerical simulations will then be used to analyze several scenarios.

The specific cost function used in the remainder of the chapter is given by

$$C(q, E) = aq^2 + b(q - E)^2 + K \qquad a, b, K > 0 \tag{4.37}$$

Here, a and b are parameters and K gives fixed costs. It can easily be verified that this cost function satisfies all first and second order conditions stated above for the general function. Furthermore, the inverse demand function is linear and is given by

$$p(nq) = \alpha - \beta nq \qquad\qquad \alpha, \beta > 0 \tag{4.38}$$

The solutions of the simulation model are given in appendix 4.C.

4.3.1 Perfect Competition

The general analysis in Section 4.2 already provided a thorough insight into the workings of the two schemes under perfect competition. The only question unanswered in that part was how the number of firms in the sector changes as it becomes regulated. We will therefore analyze this long run effect here in some detail. Furthermore, we will discuss the effect of a change in emission reduction targets, marginal abatement costs and demand function on the regulated sector.

The simulation results for perfect competition are given in Tables 4.1 to 4.6. All examples are constructed such that without regulation, firm output and emissions are 1, the number of firms is 100 and product price is 2. In Tables 4.1 to 4.3 the effect of a change in b in the cost function (4.37) is given for an emissions reduction level of 30%. In Tables 4.4 to 4.6, b is kept constant at 1, but the emission reduction level is varied between 10 and 100%. For each case, change in b or in L, there are three subcases. The three subcases differ from each other in that the demand function becomes more elastic.

In the model used for the simulations the number of firms is an integer. This differs from the model used in Section 4.2.1 where the number of firms does not have to be an integer and typically isn't. This has some implications for the results. The main difference with the general model is that in the simulations, profits may be positive. Firms will then not produce in their lowest average cost position, but at a larger output level. The results from Section 4.2.1 may now no longer hold. The simulations provide several examples of these deviations from the theory given in Section 4.2.1. In the following, we will first discuss the results for the separate schemes and after that those for combined trading.

Table 4.1: Perfect Competition: Inelastic Demand 1

$a=1$, $K=1$, $\alpha=102$, $\beta=1$, $q^0=1$, $n^0=100$, $E^0=1$, $p^0=2$, $L=70$										
	Permit Trading					Credit Trading				
b	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
1	0.966	103	0.680	2.505	0.573	0.961	104	0.673	2.093	0.575
2	0.926	107	0.654	2.938	1.086	0.924	108	0.648	2.179	1.104
3	0.897	110	0.636	3.356	1.562	0.891	112	0.625	2.256	1.593
4	0.870	113	0.620	3.740	2.001	0.859	116	0.603	2.328	2.046
5	0.844	116	0.603	4.094	2.406	0.837	119	0.588	2.412	2.486
6	0.827	118	0.593	4.455	2.801	0.809	123	0.569	2.473	2.881
7	0.804	121	0.579	4.759	3.152	0.789	126	0.556	2.548	3.272
8	0.788	123	0.569	5.078	3.502	0.770	129	0.543	2.618	3.644
9	0.773	125	0.560	5.379	3.833	0.752	132	0.530	2.685	3.998
10	0.759	127	0.551	5.664	4.147	0.735	135	0.519	2.748	4.334

Combined Trading

	Permit Sector					Credit Sector			
b	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
1	0.966	103	0.679	2.506	0.574	0.961	104	0.674	2.093
2	0.926	107	0.652	2.947	1.095	0.924	108	0.651	2.176
3	0.897	110	0.634	3.371	1.578	0.891	112	0.628	2.252
4	0.869	113	0.616	3.767	2.029	0.867	115	0.613	2.337
5	0.844	116	0.599	4.135	2.447	0.844	118	0.599	2.415
6	0.820	119	0.583	4.479	2.840	0.816	122	0.579	2.474
7	0.797	122	0.567	4.804	3.211	0.796	125	0.566	2.542
8	0.781	124	0.558	5.134	3.572	0.777	128	0.553	2.609
9	0.760	127	0.543	5.433	3.912	0.764	130	0.547	2.683
10	0.746	129	0.534	5.731	4.239	0.746	133	0.534	2.742

Welfare

	Separate Schemes			Combined trading		
b	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
1	4991	4991	9983	4991	4991	9983
2	4983	4983	9966	4983	4983	9966
3	4976	4975	9950	4975	4975	9950
4	4968	4967	9936	4967	4968	9936
5	4961	4960	9921	4960	4962	9922
6	4955	4953	9908	4953	4955	9908
7	4949	4946	9895	4946	4949	9895
8	4943	4939	9882	4940	4942	9882
9	4937	4933	9870	4933	4937	9870
10	4931	4927	9858	4927	4931	9858

In general, the simulation results confirm the results of the general analysis given in Section 4.2.1. Any deviations are due to the integer constraint on the number of firms. Regulation leads to lower industry output and higher product prices. Furthermore, the simulations show that in most cases production per firm is higher under permit than under credit trading, but that total production and the number of firms are higher under credit trading. The Tables also show that in general, the credit price is higher than the permit price. Note however that there are some irregularities in Table 4.4. For emission reduction levels of 10, 20 and 90% the firm output level is *higher* under credit trading than under permit trading, while the theoretical analysis showed that the reverse should be the case. Notice however also that the number of firms is the same under both schemes. As we showed earlier, under the same number of firms, firm output must be higher under credit trading than under permit trading. Furthermore, for emission reduction levels of 60, 70 and 80% the credit price is *lower* than the permit price.

As mentioned, a question still left open by the general analysis is the effect of regulation on the number of firms. As is shown in appendix 4.A, the number of firms may increase or decrease as a result of regulation, although credit trading always leads to a higher number of firms than permit trading. As a review of Tables 4.1-4.6 shows, the number of firms in the market depends on the slope of the inverse demand function, and thereby the elasticity of demand, and on the marginal costs of abatement. In the cases given in Tables 4.1 and 4.4, the slope of the demand function is -1 and the elasticity of demand under no regulation is -0.02. Under both permit and credit trading, the number of firms increases as compared with no regulation, although more so with credit trading than with permit trading. However, as the slope of the inverse demand function becomes flatter and demand more elastic, the number of firms in both sectors decreases as is clear from Tables 4.2 and 4.5 where the elasticity is -0.2 and Tables 4.3 and 4.6 where elasticity is -2 under no regulation. The explanation for this is as follows. Regulation increases the cost of production and thereby the price of the product. If demand is inelastic, total output will not change much, while output will decrease by a large amount if demand is elastic. At the

Table 4.2: Perfect Competition: Inelastic Demand 2

$a = 1$, $K = 1$, $\alpha = 12$, $\beta = 0.1$, $q^0 = 1$, $n^0 = 100$, $E^0 = 1$, $p^0 = 2$, $L = 70$

	Permit Trading					Credit Trading				
b	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
1	0.973	98	0.714	2.464	0.518	0.962	103	0.680	2.090	0.565
2	0.948	97	0.722	2.803	0.906	0.928	106	0.660	2.164	1.070
3	0.938	95	0.737	3.086	1.209	0.904	108	0.648	2.241	1.533
4	0.934	93	0.753	3.316	1.449	0.875	111	0.631	2.293	1.951
5	0.933	91	0.769	3.507	1.641	0.854	113	0.620	2.351	2.344
6	0.936	89	0.787	3.668	1.796	0.835	115	0.609	2.403	2.710
7	0.933	88	0.796	3.790	1.924	0.822	116	0.603	2.461	3.065
8	0.941	86	0.814	3.910	2.028	0.805	118	0.593	2.501	3.388
9	0.941	85	0.824	4.000	2.118	0.789	120	0.583	2.538	3.693
10	0.943	84	0.833	4.079	2.193	0.778	121	0.579	2.582	3.996

Combined Trading

	Permit Sector					Credit Sector			
b	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
1	0.963	99	0.693	2.467	0.541	0.971	102	0.700	2.100
2	0.941	97	0.695	2.869	0.986	0.945	104	0.698	2.173
3	0.925	95	0.698	3.211	1.361	0.922	106	0.695	2.229
4	0.913	93	0.703	3.508	1.682	0.908	107	0.698	2.286
5	0.904	91	0.708	3.771	1.962	0.902	107	0.706	2.344
6	0.899	89	0.715	4.003	2.206	0.898	107	0.714	2.394
7	0.895	87	0.723	4.211	2.420	0.894	107	0.721	2.436
8	0.894	85	0.731	4.397	2.608	0.890	107	0.727	2.473
9	0.887	84	0.733	4.550	2.776	0.887	107	0.733	2.504
10	0.890	82	0.743	4.705	2.926	0.892	106	0.746	2.544

Welfare

	Separate Schemes			Combined trading		
b	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
1	492.3	491.6	983.9	491.5	492.4	983.9
2	486.6	484.1	970.7	484.1	486.9	971.0
3	482.2	477.6	959.7	477.5	482.7	960.2
4	478.7	471.4	950.2	471.5	479.8	951.2
5	476.0	465.9	941.9	466.0	477.8	943.8
6	473.8	460.8	934.6	461.0	476.4	937.4
7	471.9	456.4	928.3	456.4	475.5	931.9
8	470.4	451.9	922.3	452.2	474.8	927.1
9	469.1	447.7	916.8	448.4	474.5	922.9
10	468.0	444.1	912.1	444.9	474.6	919.4

Table 4.3: Perfect Competition: Elastic Demand

$a = 1$, $K = 1$, $\alpha = 3$, $\beta = 0.01$, $q^0 = 1$, $n^0 = 100$, $E^0 = 1$, $p^0 = 2$, $L = 70$

	Permit Trading					Credit Trading				
b	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
1	0.996	79	0.886	2.213	0.220	0.972	96	0.729	2.066	0.487
2	0.998	75	0.933	2.252	0.257	0.957	94	0.745	2.101	0.848
3	1.003	73	0.959	2.268	0.263	0.944	93	0.753	2.122	1.150
4	1.005	72	0.972	2.276	0.265	0.937	92	0.761	2.138	1.408
5	1.000	72	0.972	2.280	0.280	0.933	91	0.769	2.151	1.634
6	1.008	71	0.986	2.284	0.268	0.931	90	0.778	2.162	1.834
7	1.006	71	0.986	2.286	0.275	0.924	90	0.778	2.169	2.040
8	1.003	71	0.986	2.288	0.281	0.924	89	0.787	2.177	2.205
9	1.002	71	0.986	2.289	0.285	0.919	89	0.787	2.182	2.385
10	1.000	71	0.986	2.290	0.289	0.922	88	0.796	2.189	2.524

Combined Trading

	Permit Sector					Credit Sector			
b	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
1	0.991	72	0.839	2.287	0.305	0.991	95	0.838	2.059
2	0.991	64	0.895	2.366	0.385	0.992	93	0.896	2.077
3	0.993	60	0.923	2.404	0.419	0.994	92	0.924	2.086
4	0.991	58	0.940	2.423	0.435	0.997	91	0.942	2.093
5	0.998	56	0.954	2.441	0.445	0.996	91	0.952	2.094
6	0.996	56	0.958	2.442	0.451	1.000	90	0.962	2.100
7	0.997	55	0.964	2.452	0.459	0.999	90	0.967	2.101
8	1.000	54	0.972	2.460	0.459	0.999	90	0.971	2.101
9	0.997	54	0.971	2.462	0.467	0.999	90	0.973	2.101
10	1.001	53	0.978	2.469	0.467	0.999	90	0.976	2.101

Welfare

	Separate Schemes			Combined trading		
b	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
1	46.77	44.03	90.80	44.22	47.61	91.83
2	46.21	40.87	87.08	42.12	47.98	90.09
3	45.99	38.73	84.72	40.94	48.28	89.22
4	45.87	37.28	83.15	40.35	48.49	88.84
5	45.80	36.30	82.10	39.72	48.66	88.38
6	45.75	35.63	81.38	39.74	48.74	88.48
7	45.71	34.67	80.39	39.37	48.82	88.19
8	45.69	34.40	80.09	39.08	48.90	87.98
9	45.67	33.69	79.36	39.02	48.94	87.96
10	45.65	33.66	79.31	38.69	49.00	87.69

Table 4.4: Perfect Competition: Change in emission reduction 1

$a = 1$, $b = 1$, $K = 1$, $\alpha = 102$, $\beta = 1$, $q^0 = 1$, $n^0 = 100$, $E^0 = 1$, $p^0 = 2$										
	Permit Trading					Credit Trading				
EmRed	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
10	0.998	100	0.900	2.192	0.196	1.000	100	0.900	2.020	0.200
20	0.987	101	0.792	2.362	0.389	0.990	101	0.792	2.058	0.395
30	0.966	103	0.680	2.505	0.573	0.961	104	0.673	2.093	0.575
40	0.938	106	0.566	2.618	0.743	0.933	107	0.561	2.163	0.745
50	0.903	110	0.455	2.702	0.896	0.899	111	0.450	2.245	0.897
60	0.863	115	0.348	2.756	1.030	0.859	116	0.345	2.334	1.029
70	0.827	120	0.250	2.807	1.153	0.823	121	0.248	2.449	1.150
80	0.787	126	0.159	2.831	1.257	0.783	127	0.158	2.565	1.251
90	0.746	133	0.075	2.832	1.341	0.747	133	0.075	2.701	1.343
100	0.708	140	0.000	2.833	1.417	0.708	140	0.000	2.833	1.417

Combined Trading

	Permit Sector					Credit Sector			
EmRed	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
10	0.998	100	0.899	2.194	0.198	1.000	100	0.901	2.019
20	0.987	101	0.791	2.365	0.392	0.990	101	0.794	2.057
30	0.966	103	0.679	2.506	0.574	0.961	104	0.674	2.093
40	0.929	107	0.559	2.599	0.741	0.933	107	0.563	2.162
50	0.903	110	0.456	2.699	0.893	0.899	111	0.452	2.243
60	0.863	115	0.348	2.756	1.030	0.859	116	0.344	2.335
70	0.820	121	0.247	2.787	1.147	0.823	121	0.249	2.447
80	0.787	126	0.163	2.823	1.249	0.783	127	0.159	2.564
90	0.746	133	0.075	2.833	1.342	0.747	133	0.076	2.700
100	0.708	140	0.000	2.833	1.417	0.708	140	0.000	2.833

Welfare

	Separate Schemes			Combined trading		
EmRed	PT	CT	Tot	CPT	CCT	Tot
10	4999	4999	9998	4999	4999	9998
20	4996	4996	9992	4996	4996	9992
30	4991	4991	9983	4991	4991	9983
40	4985	4985	9969	4985	4985	9969
50	4977	4977	9953	4977	4977	9953
60	4967	4967	9934	4967	4967	9934
70	4956	4956	9912	4956	4956	9912
80	4944	4944	9888	4944	4944	9888
90	4931	4931	9863	4931	4931	9863
100	4918	4918	9835	4918	4918	9835

Table 4.5: Perfect Competition: Change in emission reduction 2

$a=1,\ b=1,\ K=1,\ \alpha=12,\ \beta=0.1,\ q^0=1,\ n^0=100,\ E^0=1,\ p^0=2$										
	Permit Trading					Credit Trading				
$EmRed$	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
10	1.003	98	0.918	2.174	0.169	0.998	100	0.900	2.016	0.197
20	0.988	98	0.816	2.319	0.343	0.985	101	0.792	2.047	0.387
30	0.973	98	0.714	2.464	0.518	0.962	103	0.680	2.090	0.565
40	0.943	100	0.600	2.571	0.686	0.937	105	0.571	2.160	0.731
50	0.907	103	0.485	2.657	0.843	0.904	108	0.463	2.238	0.882
60	0.874	106	0.377	2.740	0.993	0.864	112	0.357	2.323	1.014
70	0.831	111	0.270	2.782	1.121	0.825	116	0.259	2.428	1.133
80	0.791	116	0.172	2.821	1.238	0.787	120	0.167	2.553	1.241
90	0.751	122	0.082	2.840	1.338	0.750	124	0.081	2.696	1.339
100	0.710	129	0.000	2.840	1.420	0.710	129	0.000	2.840	1.420

Combined Trading

	Permit Sector					Credit Sector			
$EmRed$	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
10	1.002	98	0.911	2.185	0.182	0.999	100	0.908	2.015
20	0.986	98	0.804	2.336	0.364	0.986	101	0.804	2.043
30	0.963	99	0.693	2.467	0.541	0.971	102	0.700	2.100
40	0.941	100	0.587	2.590	0.708	0.938	105	0.584	2.152
50	0.906	103	0.474	2.673	0.862	0.905	108	0.474	2.230
60	0.866	107	0.364	2.735	1.003	0.871	111	0.370	2.330
70	0.830	111	0.265	2.789	1.129	0.832	115	0.267	2.438
80	0.791	116	0.173	2.820	1.238	0.788	120	0.169	2.551
90	0.746	123	0.079	2.825	1.333	0.751	124	0.084	2.691
100	0.710	129	0.000	2.840	1.420	0.710	129	0.000	2.840

Welfare

	Separate Schemes			Combined trading		
EmRed	PT	CT	Tot	CPT	CCT	Tot
10	499.2	499.0	998.2	499.0	499.2	998.2
20	496.6	496.2	992.8	496.2	496.6	992.8
30	492.3	491.6	983.9	491.5	492.4	983.9
40	486.3	485.4	971.7	485.4	486.3	971.7
50	478.6	477.7	956.4	477.7	478.7	956.3
60	469.5	468.6	938.1	468.5	469.7	938.1
70	458.9	458.3	917.2	458.3	459.1	917.4
80	447.1	446.8	894.0	447.2	447.1	894.3
90	434.3	434.2	868.6	434.0	434.8	868.8
100	420.6	420.6	841.2	420.9	420.9	841.7

same time, regulation decreases the optimal production level for the firm and more so with credit trading than with permit trading. Then, when emissions are regulated, total output does not decrease much with inelastic demand, while optimal output does decrease, so that more firms can exist in the market. When demand is more elastic, total output decreases more and fewer firms can survive in the market. At some point, demand decreases by so much with an increase in price that the total number of firms decreases compared with no regulation.

It is interesting to see that in general the outcome depends on the elasticity of demand. For example, the higher the elasticity of demand, the lower the emissions quota price, and the larger the difference between the permit and credit price. With high elasticity, an increase in price gives a relatively large decrease in output and thereby also in emissions. Hence, the price on emissions does not need to be very high to achieve a certain reduction in emissions. But credit trading gives a smaller decrease in emissions for a given emissions quota price because of the implicit output subsidy that is inherent in this system. The effect of the output subsidy will be larger, the larger the elasticity is. Hence, the credit price must be higher than the permit price and the difference must be larger when demand is more elastic.

For combined trading, the simulations show that in general, permits flow to the credit market and the resulting emission quota price lies in between the original permit and credit prices. The result is an increase in production in the credit sector, both per firm and in total, and a decrease in production in the permit sector. So combining the two schemes leads to even larger inefficiencies in that credit sector production is increased above the already too high level. However, also here the integer constraint on the number of firms gives deviations from the theoretical analysis of Section 4.2.1. In several cases the product price in the credit sector is higher under combined trading than under separate schemes. This occurs in Table 4.1 for $b = 4, 5, 6$, Table 4.2 for $b = 1, 2$, Table 4.4 for an emission reduction level of 60% and in Table 4.5 for emission reduction levels of 30, 60 and 70%. This does however not imply that in these cases, production in the permit sector is stimulated. This occurs only in Table 4.5 for an emission reduction level of 60%. Note

Table 4.6: Perfect Competition: Change in emission reduction 3

$a = 1,\ b = 1,\ K = 1,\ \alpha = 3,\ \beta = 0.01,\ q^0 = 1,\ n^0 = 100,\ E^0 = 1,\ p^0 = 2$										
	Permit Trading					Credit Trading				
$EmRed$	q^p	n^p	E^p	p^p	R^p	q^c	n^c	E^c	p^c	R^c
10	1.001	93	0.968	2.069	0.067	0.998	99	0.909	2.012	0.178
20	1.000	86	0.930	2.140	0.140	0.987	98	0.816	2.033	0.341
30	0.996	79	0.886	2.213	0.220	0.972	96	0.729	2.067	0.486
40	0.989	72	0.833	2.288	0.311	0.951	94	0.638	2.106	0.625
50	0.983	64	0.781	2.371	0.404	0.930	90	0.556	2.163	0.750
60	0.971	56	0.714	2.456	0.514	0.901	86	0.465	2.225	0.872
70	0.949	48	0.625	2.545	0.647	0.870	80	0.375	2.304	0.990
80	0.917	39	0.513	2.642	0.809	0.836	71	0.282	2.407	1.108
90	0.860	29	0.345	2.751	1.031	0.789	58	0.172	2.542	1.234
100	0.708	24	0.000	2.830	1.415	0.708	24	0.000	2.830	1.415

Combined Trading

	Permit Sector					Credit Sector			
$EmRed$	q^p	n^p	E^p	p^p	R	q^c	n^c	E^c	p^c
10	1.001	90	0.953	2.099	0.097	1.000	99	0.952	2.010
20	0.997	81	0.898	2.192	0.198	0.999	97	0.900	2.031
30	0.991	72	0.839	2.287	0.305	0.991	95	0.838	2.059
40	0.978	64	0.769	2.374	0.418	0.980	92	0.770	2.099
50	0.967	55	0.700	2.468	0.534	0.965	88	0.699	2.150
60	0.947	47	0.616	2.555	0.661	0.946	83	0.615	2.215
70	0.920	39	0.519	2.641	0.801	0.917	77	0.516	2.294
80	0.879	32	0.399	2.719	0.960	0.881	68	0.401	2.401
90	0.818	26	0.243	2.787	1.151	0.820	56	0.245	2.541
100	0.708	24	0.000	2.830	1.415	0.708	24	0.000	2.830

Welfare

	Separate Schemes			Combined trading		
EmRed	PT	CT	Tot	CPT	CCT	Tot
10	49.66	49.21	98.87	49.30	49.76	99.06
20	48.60	47.08	95.68	47.36	49.00	96.36
30	46.77	44.03	90.80	44.22	47.61	91.83
40	44.10	40.04	84.14	40.17	45.45	85.61
50	40.50	35.60	76.10	35.07	42.50	77.57
60	35.85	30.27	66.13	29.33	38.37	67.70
70	30.01	24.42	54.43	22.94	32.78	55.72
80	22.73	18.02	40.75	16.33	25.31	41.64
90	13.56	10.66	24.22	9.534	15.02	24.55
100	1.472	1.472	2.943	1.472	1.472	2.944

that in this case the emissions quota price for combined trading lies between the permit and credit price. Note also that in the same table for emission reduction levels of 80 and 90% the product price in the permit sector is lower under combined trading than in the separate scheme. In these two cases, both sectors are stimulated as a result of combining them. Another irregularity is that in certain cases the emissions quota price for combined trading lies below both the permit and credit price for the separate schemes. This is the case in Table 4.4 for an emission reduction level of 40, 50, 70 and 80% and in Table 4.5 for emission reduction levels of 90%. The explanation for these differences with the results of Section 4.2.1 is basically the same as the one given for the separate schemes. When the number of firms is an integer, production occurs in a point away from the lowest cost point and production under one scheme may be further away from this point than for the other scheme. This makes all of the above mentioned anomalies possible.

Concerning welfare, we showed in Section 4.2.3 that permit trading always leads to higher welfare than credit trading. This is also shown in Tables 4.1-4.6, where welfare in all cases is highest under permit trading. A more interesting question is whether combining a permit and a credit trading scheme will lead to an increase or a decrease in welfare. In Section 4.2.4 we showed that both results are possible. The simulations illustrate this, although they more often show an increase in welfare than a decrease. Actually, the only instance where welfare decreases as a result of combining the two schemes is given in Table 4.5 for an emission reduction level of 50%. In all other cases, welfare either does not change or increases when the two schemes are combined. This shows that even small differences in marginal abatement costs can trigger an increase in welfare from combining the two schemes.

4.3.2 Imperfect Competition

In Section 4.2 we gave a theoretical analysis of permit and credit trading under imperfect competition. For the case of equal numbers of firms under both schemes, we showed that credit trading leads to higher firm and total

Table 4.7: Imperfect Competition 1

$a = 1$, $K = 100$, $\alpha = 50$, $\beta = 1$
$q^0 = 7.14$, $n^0 = 4$, $E^0 = 7.14$, $p^0 = 21.43$, $\pi^0 = 2.04$ $L = 20$

	Permit Trading						Credit Trading					
b	q^p	n^p	E^p	p^p	π^p	R^p	q^c	n^c	E^c	p^c	π^c	R^c
1	7.92	3	6.67	26.25	26.91	2.50	6.90	4	5.00	22.42	3.44	3.79
2	7.67	3	6.67	27.00	19.56	4.00	6.71	4	5.00	23.15	4.50	6.85
3	7.50	3	6.67	27.50	14.58	5.00	6.57	4	5.00	23.73	5.36	9.40
4	7.38	3	6.67	27.86	11.00	5.71	6.45	4	5.00	24.20	6.09	11.60
5	7.29	3	6.67	28.13	8.29	6.25	6.35	4	5.00	24.59	6.73	13.52
6	7.22	3	6.67	28.33	6.17	6.67	6.27	4	5.00	24.92	7.29	15.23
7	7.17	3	6.67	28.50	4.47	7.00	6.20	4	5.00	25.21	7.80	16.76
8	7.12	3	6.67	28.64	3.08	7.27	6.13	4	5.00	25.46	8.26	18.15
9	7.08	3	6.67	28.75	1.91	7.50	6.08	4	5.00	25.68	8.69	19.43
10	7.05	3	6.67	28.85	0.92	7.69	6.03	4	5.00	25.88	9.08	20.60
20	10.00	2	10.00	30.00	100.00	0.00	5.72	4	5.00	27.11	11.98	28.87
50	10.00	2	10.00	30.00	100.00	0.00	5.40	4	5.00	28.40	16.22	39.95

Combined Trading

	Permit Sector						Credit Sector				
b	q^p	n^p	E^p	p^p	π^p	R	q^c	n^c	E^c	p^c	π^c
1	7.80	3	6.21	26.59	24.30	3.18	6.93	4	5.34	22.26	2.67
2	7.43	3	6.08	27.71	14.10	5.42	6.80	4	5.44	22.82	2.81
3	7.15	3	5.98	28.54	6.54	7.08	6.70	4	5.52	23.21	2.74
4	6.94	3	5.89	29.18	0.69	8.36	6.62	4	5.58	23.50	2.59
5	8.33	2	7.49	33.34	42.19	8.36	6.62	4	5.79	23.50	1.72
6	8.33	2	7.63	33.34	41.61	8.36	6.62	4	5.93	23.50	1.13
7	8.33	2	7.73	33.34	41.20	8.36	6.62	4	6.03	23.50	0.72
8	8.32	2	7.80	33.35	40.78	8.38	6.62	4	6.10	23.51	0.41
9	8.25	2	7.77	33.50	38.29	8.74	6.60	4	6.12	23.59	0.26
10	8.19	2	7.74	33.62	36.14	9.06	6.59	4	6.13	23.66	0.12
20	7.04	3	6.85	28.87	0.00	7.73	7.78	3	7.59	26.66	39.01
50	7.06	3	6.98	28.82	0.00	7.64	7.79	3	7.71	26.64	38.54

Welfare

	Separate Schemes			Combined trading		
b	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
1	412.98	394.52	807.50	406.00	399.31	805.31
2	403.40	378.18	781.58	389.53	390.60	780.12
3	396.92	366.57	763.50	376.65	384.75	761.40
4	392.47	357.13	749.60	366.54	380.54	747.08
5	389.15	349.55	738.71	348.39	384.06	732.45
6	386.48	343.54	730.02	349.56	386.42	735.98
7	384.79	338.52	723.31	350.40	388.10	738.50
8	382.93	333.97	716.90	350.70	389.32	740.02
9	381.41	330.41	711.82	348.60	388.85	737.46
10	380.40	327.23	707.63	346.65	388.66	735.31
20	400.00	309.79	709.79	382.02	410.87	792.89
50	400.00	298.08	698.08	384.21	412.53	796.74

production and a higher emissions quota price than permit trading. The results were less clear cut for the case where the number of firms is not identical under the two schemes. The only results that could be derived are that the number of firms and total output will be higher under credit than under permit trading. Furthermore, it was shown that it depends on the circumstances which instrument will lead to higher welfare and that the effect of combined trading on welfare was unclear.

In this part, we will try to answer the questions left open by the general analysis. Furthermore, as was done under perfect competition, the effects of varying emission reduction targets, marginal abatement costs and the demand function on the regulated sector will be discussed.

The simulation consists basically of two cases with different demand functions. For both cases, b, a measure for the marginal abatement costs in equation (4.37), and the emission reduction level are varied to yield different results. Furthermore, the welfare levels and some special cases under permit and credit trading are discussed. The simulation results for imperfect competition are shown in Tables 4.7 to 4.13. In Tables 4.7, 4.9 and 4.11 the inverse demand function is relatively flat, while in the other Tables, the slope is relatively steep. In all cases, there are four firms when there is no regulation. However, because the demand functions are different, firm production and emissions are different in the two cases. For both demand functions, demand is inelastic in all cases.

The first main result that can be derived from the simulations is that the number of firms under credit trading is always at least as high as that under permit trading. This result is expected since the demand function is linear, so that inequality (4.25) holds. Furthermore, the product price p is always lower under credit trading. This confirms the results of the analysis in Section 4.2. The simulations also confirm the results of the general analysis for the case where the number of firms is equal under the two schemes. Here, firm and total output are higher under credit trading and the credit price is higher than the permit price.

Another general result is that the number of firms can increase or decrease as a result of regulation. This holds under both instruments. As with perfect competition, the number of firms will increase when demand is very inelastic (Tables 4.8 and 4.12) and decrease when demand is more elastic (Tables 4.7 and 4.9). The explanation for this is the same as under perfect competition: regulation lowers the optimal production level, and more so under credit trading than under permit trading, while demand decreases more, the more elastic demand is. This implies that there will be room for more firms the more inelastic demand is.

For the case where the number of firms is higher under credit trading than under permit trading, the general analysis did not yield many clear results. In the simulations, firm output is always lower under credit trading than under permit trading. However, this is not a conclusive result since we only have a few simulations.

As already mentioned, the product price is lower under credit trading than under permit trading. Furthermore, the product price increases with b (see Tables 4.7 and 4.8). Since b is the parameter controlling the size of the marginal abatement costs this result is expected. One might also expect that prices rise the larger the total emission reduction is (i.e., the lower L is). Although this holds as long as the number of firms remains the same or decreases, it may not hold when the number of firms increases. This is shown in Table 4.12, for both permit trading and credit trading, where the product price falls when the number of firms increases, even though the emission reduction level is higher. Here, two effects are at play. In the first place, the higher emission reduction level will increase marginal abatement costs. However, if at the same time profits rise with stricter policy, as is the case here, entry will take place at some point. As is shown in appendix 4.B, entry leads to higher total output and lower product price. In some cases, the output-increasing effect of entry is larger than the cost-increasing effect of stricter policy so that prices fall.

Also under imperfect competition, the permit price may be higher than the credit price. This is shown in Table 4.12 for emission reduction levels of 40 to 80%. Notice that at these emission reduction levels there are four firms in the permit sector and five in the credit sector. At the same time, profits are high in the permit sector and low in the credit sector. This implies

Table 4.8: Imperfect Competition 2

$a = 1$, $K = 100$, $\alpha = 150$, $\beta = 6.6$

$q^0 = 4.29$, $n^0 = 4$, $E^0 = 4.29$, $p^0 = 36.86$, $\pi^0 = 39.59$ $L = 12.00$

	Permit Trading						Credit Trading					
b	q^p	n^p	E^p	p^p	π^p	R^p	q^c	n^c	E^c	p^c	π^c	R^c
1	4.22	4	3.00	38.69	36.58	2.43	4.25	4	3.00	37.75	40.85	2.50
2	4.15	4	3.00	40.34	33.80	4.62	3.55	5	2.40	32.69	0.92	4.62
3	4.10	4	3.00	41.82	31.21	6.59	3.53	5	2.40	33.47	1.87	6.79
4	4.05	4	3.00	43.17	28.83	8.37	3.51	5	2.40	34.20	2.77	8.87
5	4.00	4	3.00	44.40	26.60	10.00	3.49	5	2.40	34.89	3.62	10.88
6	3.96	4	3.00	45.52	24.53	11.49	3.47	5	2.40	35.55	4.42	12.82
7	3.92	4	3.00	46.56	22.59	12.86	3.45	5	2.40	36.18	5.17	14.69
8	3.88	4	3.00	47.51	20.78	14.12	3.43	5	2.40	36.77	5.90	16.50
9	3.85	4	3.00	48.38	19.08	15.28	3.41	5	2.40	37.34	6.58	18.25
10	3.82	4	3.00	49.20	17.49	16.36	3.40	5	2.40	37.89	7.24	19.95
20	3.60	4	3.00	54.96	5.70	24.00	3.26	5	2.40	42.29	12.47	34.55
50	4.28	3	4.00	65.19	43.47	28.35	3.04	5	2.40	49.70	21.36	63.95

Combined Trading

	Permit Sector						Credit Sector				
b	q^p	n^p	E^p	p^p	π^p	R	q^c	n^c	E^c	p^c	π^c
1	4.22	4	2.99	38.71	36.57	2.45	4.25	4	3.03	37.73	40.79
2	4.15	4	3.00	40.34	33.80	4.62	3.55	5	2.40	32.69	0.92
3	4.09	4	2.98	41.91	31.15	6.69	3.53	5	2.42	33.43	1.77
4	4.04	4	2.96	43.37	28.64	8.64	3.51	5	2.43	34.11	2.53
5	3.99	4	2.94	44.74	26.28	10.46	3.49	5	2.45	34.74	3.19
6	3.94	4	2.92	46.04	24.03	12.17	3.47	5	2.46	35.33	3.78
7	3.89	4	2.91	47.25	21.90	13.78	3.46	5	2.47	35.87	4.30
8	3.85	4	2.89	48.40	19.88	15.30	3.44	5	2.49	36.38	4.76
9	3.81	4	2.88	49.49	17.95	16.74	3.43	5	2.50	36.85	5.17
10	3.77	4	2.86	50.52	16.12	18.11	3.42	5	2.51	37.30	5.53
20	3.47	4	2.75	58.47	1.62	28.65	3.32	5	2.60	40.58	7.58
50	3.79	3	3.37	74.88	18.32	42.25	3.20	5	2.78	44.41	7.01

Welfare

	Separate Schemes			Combined trading		
b	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
1	1115,36	1117,38	2232,73	1115,43	1117,50	2232,93
2	1100,35	1045,14	2145,49	1100,35	1045,14	2145,49
3	1091,16	1037,66	2128,83	1088,13	1037,98	2126,11
4	1081,43	1030,11	2111,54	1078,48	1030,64	2109,12
5	1071,20	1022,56	2093,76	1068,29	1023,92	2092,21
6	1063,67	1015,09	2078,77	1057,73	1016,93	2074,66
7	1055,87	1007,70	2063,57	1047,19	1013,61	2060,80
8	1047,68	1000,29	2047,97	1038,90	1007,60	2046,50
9	1042,23	993,03	2035,25	1030,91	1004,49	2035,41
10	1036,62	989,27	2025,89	1021,95	1001,53	2023,47
20	995,07	940,07	1935,14	957,15	974,86	1932,01
50	1014,80	869,11	1883,92	908,89	959,98	1868,87

Table 4.9: Imperfect Competition 3

$a = 1$, $b = 1$, $K = 100$, $\alpha = 50$, $\beta = 1$, $q^0 = 7.14$, $n^0 = 4$, $E^0 = 7.14$, $p^0 = 21.43$, $\pi^0 = 2.04$

	Permit Trading						Credit Trading					
%Red	q^p	n^p	E^p	p^p	π^p	R^p	q^c	n^c	E^c	p^c	π^c	R^c
10	—*	—	—	—	—	—	7.08	4	6.43	21.67	2.87	1.31
20	8.16	3	7.62	25.54	33.29	1.07	7.00	4	5.71	22.00	3.34	2.57
30	7.91	3	6.67	26.25	26.91	2.50	6.90	4	5.00	22.42	3.44	3.79
40	7.68	3	5.71	26.96	21.78	3.93	6.77	4	4.29	22.92	3.16	4.97
50	7.44	3	4.76	27.68	17.90	5.36	6.62	4	3.57	23.51	2.51	6.10
60	7.20	3	3.81	28.39	15.26	6.79	6.46	4	2.86	24.18	1.45	7.20
70	6.96	3	2.86	29.11	13.87	8.21	—*	—	—	—	—	—
80	6.73	3	1.90	29.82	13.73	9.64	6.96	3	1.90	29.13	28.73	10.10
90	6.49	3	0.95	30.54	14.83	11.07	6.62	3	0.95	30.13	23.52	11.34
100	6.25	3	0.00	31.25	17.19	12.50	6.25	3	0.00	31.25	17.19	12.50

Combined Trading

	Permit Sector						Credit Sector				
%Red	q^p	n^p	E^p	p^p	π^p	R	q^c	n^c	E^c	p^c	π^c
10	8.25	3	7.99	25.26	36.08	0.52	7.12	4	6.86	21.52	2.26
20	8.02	3	7.09	25.93	29.61	1.86	7.04	4	6.11	21.84	2.62
30	7.80	3	6.21	26.59	24.30	3.18	6.93	4	5.34	22.26	2.67
40	7.59	3	5.35	27.24	20.12	4.48	6.81	4	4.56	22.78	2.44
50	7.37	3	4.50	27.88	17.03	5.76	6.65	4	3.77	23.39	1.92
60	7.17	3	3.66	28.50	14.96	7.01	6.47	4	2.97	24.11	1.09
70	6.96	3	2.83	29.13	13.85	8.26	7.32	3	3.18	28.06	31.95
80	6.69	3	1.76	29.93	13.82	9.87	6.99	3	2.06	29.04	28.26
90	6.47	3	0.86	30.60	15.00	11.20	6.64	3	1.04	30.07	23.24
100	6.25	3	0.00	31.25	17.19	12.50	6.25	3	0.00	31.25	17.19

Welfare

	Separate Schemes			Combined trading		
%Red	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
10	—*	412.86	—	413.87	415.37	829.24
20	423.60	405.40	829.00	418.10	409.77	827.87
30	412.76	394.16	806.92	406.20	399.71	805.90
40	398.01	379.32	777.33	391.23	385.20	776.43
50	379.34	360.99	740.33	373.40	366.24	739.64
60	356.77	339.23	696.00	352.90	342.70	695.60
70	330.28	—	—	329.33	344.73	674.06
80	299.88	303.97	603.85	294.78	308.95	603.72
90	265.57	268.02	533.58	262.16	271.38	533.54
100	227.34	227.34	454.69	227.34	227.34	454.69

* — indicates that the emission reduction level is not obtainable (see Tables 4.10 and 4.11).

Table 4.10: Some L not obtainable with permit trading

$a=1$, $b=1$, $K=100$, $\alpha=50$, $\beta=1$, $q^0=7.14$, $n^0=4$, $E^0=7.14$, $p^0=21.43$, $\pi^0=2.04$								
% em.red.	L	$\sum E$	q^p	n^p	E^p	p^p	π^p	R^p
4.6729	27.2363	27.2363	7.0687	4	6.8091	21.7253	0.0000	0.5192
4.6732	27.2362	25.0000	8.3333	3	8.3333	25.0000	38.8889	0.0000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
12.4999	25.0000	25.0000	8.3333	3	8.3333	25.0000	38.8889	0.0000
12.5006	24.9998	24.9998	8.3333	3	8.3333	25.0000	38.8884	0.0001

Table 4.11: Some L are not obtainable with credit trading

$a=1$, $b=1$, $K=100$, $\alpha=50$, $\beta=1$, $q^0=7.14$, $n^0=4$, $E^0=7.14$, $p^0=21.43$, $\pi^0=2.04$								
$\bar{e}$	% em.red.	L	q^c	n^c	E^c	p^c	π^c	R^c
0.3438	69.8225	8.6221	6.2703	4	2.1555	24.9187	0.0000	8.2296
0.3438	74.2603	7.3542	7.1310	3	2.4514	28.6071	31.2473	9.3591

that firm production in the credit sector is close to the zero profit point, while that in the permit sector occurs at less efficient levels. In this case, firm production in the permit sector takes place at such an inefficient level that marginal abatement costs become higher than in the credit sector, even though credit trading is a less efficient form of regulation. Note also that the permit price falls as we move from 80 to 90% emission reduction. At 90% a new firm has entered the permit sector and firm production is suddenly very close to the zero profit level, and therefore much more efficient than before. Hence, with imperfect competition, firm entry may lead to lower marginal abatement costs and thereby lower emission quota prices.

We now turn to the effect of the two schemes on profits. In Tables 4.7 and 4.8, for a given number of firms, under permit trading profits decrease in b, while under credit trading they increase in b. Furthermore, with the number of firms constant, regulation leads to a decrease in profits with permit trading and to an increase with credit trading. Basically, regulation has two effects. First of all, regulation increases production costs and thereby lowers profits. Second, it lowers firm production. As long as the number of firms remains constant, this also means lower total production and thereby higher price.

Since production under oligopoly is higher than the joint profit maximizing level (the monopoly level) the latter effect gives higher profits for all firms. It is as if the government through its policy has made the firms commit to a lower production level. The simulations show that under permit trading the former effect is stronger than the latter, while the reverse is the case under credit trading. The intuition for this is that under permit trading, output is already closer to the monopoly level than under credit trading. Reducing output will then have a smaller positive effect on profits under permit trading than under credit trading.

The effect of decreasing L on profits is different at different levels of L. For permit trading profits first fall given n, and then rise as L diminishes (Tables 4.9 and 4.12). Table 4.9 shows the reverse happening for credit trading, while in Table 4.12 profits rise continually with lower L. With a b higher than 3.3, credit trading always results initially in a rise in profit and then a decline with lower L (not shown).

In Propositions 18 and 19 we showed that under both schemes it is possible that certain emission levels cannot be attained. This is illustrated in Tables 4.9 to 4.11. As Table 4.10 shows, under the given circumstances, emission reduction levels between 4.67% and 12.5% are not obtainable with permit trading. The reason is that at emission reduction level 4.67% the number of firms in the market decreases to three and the emission limit becomes non-binding. Here, the three remaining firms emit a total amount of 25 without regulation, which corresponds to an emission reduction level of 12.5%. Only at an emission reduction level higher than 12.5% does the emission limit become binding again. In this case, the non-obtainability of certain emission levels stems from the fact that as the limit decreases, the number of firms decreases as well. Then, in certain cases, the unconstrained emission level of the firms is lower than the emission limit.

For credit trading something similar happens. Here, the government does not set a total emission limit, but a relative standard. Then, as the relative standard is lowered, exit may occur, as is shown in Tables 4.9 and 4.11. As a result, total output decreases, but since the relative standard is fixed at this level, total emissions will decrease too. In Table 4.11 this

Table 4.12: Imperfect Competition 4

$a=1$, $b=1$, $K=100$, $\alpha=150$, $\beta=6.6$, $q^0=4.29$, $n^0=4$, $E^0=4.29$, $p^0=36.86$, $\pi^0=39.59$

	Permit Trading						Credit Trading					
%Red	q^p	n^p	E^p	p^p	π^p	R^p	q^c	n^c	E^c	p^c	π^c	R^c
10	4.26	4	3.86	37.47	38.25	0.81	4.28	4	3.86	37.07	40.08	0.85
20	4.24	4	3.43	38.08	37.25	1.62	4.27	4	3.43	37.36	40.49	1.68
30	4.22	4	3.00	38.69	36.58	2.43	4.25	4	3.00	37.75	40.85	2.50
40	4.19	4	2.57	39.30	36.25	3.24	3.57	5	2.06	32.30	0.20	3.02
50	4.17	4	2.14	39.92	36.26	4.05	3.55	5	1.71	32.80	0.50	3.67
60	4.15	4	1.71	40.53	36.60	4.86	3.53	5	1.37	33.38	0.78	4.33
70	4.12	4	1.29	41.14	37.28	5.66	3.51	5	1.03	34.03	1.06	4.97
80	4.10	4	0.86	41.75	38.30	6.49	3.49	5	0.69	34.76	1.32	5.61
90	3.46	5	0.34	35.95	0.47	6.23	3.47	5	0.34	35.57	1.57	6.25
100	3.44	5	0.00	36.47	1.79	6.88	3.44	5	0.00	36.47	1.79	6.88

Combined Trading

	Permit Sector						Credit Sector				
%Red	q^p	n^p	E^p	p^p	π^p	R	q^c	n^c	E^c	p^c	π^c
10	4.26	4	3.85	37.48	38.23	0.83	4.28	4	3.87	37.06	40.06
20	4.24	4	3.42	38.10	37.22	1.65	4.27	4	3.44	37.35	40.47
30	4.22	4	2.99	38.71	36.57	2.45	4.25	4	3.03	37.73	40.79
40	4.20	4	2.64	39.21	36.28	3.12	3.57	5	2.01	32.34	0.33
50	4.18	4	2.25	39.76	36.22	3.85	3.55	5	1.63	32.88	0.74
60	4.16	4	1.87	40.30	36.44	4.57	3.53	5	1.25	33.51	1.18
70	4.14	4	1.49	40.85	36.91	5.29	3.51	5	0.87	34.22	1.63
80	4.12	4	1.13	41.35	37.60	5.96	3.49	5	0.50	34.99	2.01
90	3.46	5	0.34	35.96	0.49	6.24	3.47	5	0.35	35.57	1.54
100	3.44	5	0.00	36.47	1.79	6.88	3.44	5	0.00	36.47	1.79

Welfare

	Separate Schemes			Combined trading		
%Red	**PT**	**CT**	**Tot**	**CPT**	**CCT**	**Tot**
10	1124.85	1126.57	2251.42	1124.78	1126.62	2251.40
20	1120.17	1123.18	2243.35	1119.99	1123.31	2243.30
30	1114.11	1118.02	2232.13	1113.95	1118.36	2232.32
40	1106.67	1050.51	2157.18	1107.89	1049.57	2157.47
50	1097.86	1043.10	2140.96	1100.26	1041.18	2141.44
60	1087.67	1034.32	2122.00	1091.56	1031.10	2122.66
70	1076.11	1024.17	2100.28	1081.82	1019.34	2101.17
80	1063.17	1012.65	2075.82	1071.70	1006.61	2078.31
90	998.46	999.74	1998.20	998.26	999.97	1998.22
100	985.44	985.44	1970.88	985.44	985.44	1970.88

Table 4.13: Some L can be obtained with different $\bar{e}$

$a=1,\ b=1,\ K=100,\ \alpha=150,\ \beta=6.6$								
$q^0=4.29,\ n^0=4,\ E^0=4.29,\ p^0=36.86,\ \pi^0=39.59$								
Credit Trading								
$\bar{e}$	%.red.	q^c	n^c	E^c	p^c	π^c	R^c	L
0.6730	33.317	4.246	4	2.858	37.895	40.956	2.777	11.431
0.6670	33.928	4.245	4	2.832	37.923	40.974	2.827	11.327
0.6610	34.539	4.244	4	2.806	37.952	40.993	2.878	11.222
0.6550	35.150	4.243	4	2.779	37.981	41.011	2.928	11.117
0.6490	35.761	4.242	4	2.753	38.010	41.028	2.978	11.012
0.6430	36.372	4.241	4	2.727	38.040	41.046	3.028	10.908
0.6396	36.715	4.240	4	2.712	38.057	41.055	3.056	10.849
0.6396	33.296	3.576	5	2.287	32.008	0.000	2.577	11.435
0.6370	33.576	3.575	5	2.277	32.019	0.009	2.596	11.387
0.6310	34.217	3.574	5	2.255	32.046	0.028	2.638	11.277
0.6250	34.857	3.575	5	2.234	32.073	0.047	2.680	11.167
0.6190	35.497	3.573	5	2.212	32.100	0.067	2.722	11.058
0.6130	36.137	3.572	5	2.190	32.127	0.086	2.765	10.948
0.6070	36.777	3.571	5	2.168	32.155	0.105	2.807	10.838

happens when the relative standard is 0.3438. Here, profits become zero and a firm will exit. In this case, emission reduction levels between 69.82% and 74.26% are unobtainable.

Under credit trading it is also possible that certain emission levels can be reached by two different relative standards (see Proposition 19). This is illustrated in Table 4.13. Table 4.13 shows what happens as the relative standard is tightened from 0.673 to 0.607. At first, profits increase as the emission limit decreases. Then, when the relative standard is 0.6396, profits become so large that entry occurs. This results in an increase in total output. Since the relative standard determines allowed emissions per unit of output, this also implies that total emissions will increase, which is also shown in the Table. Only at a relative standard of about 0.61 are total emissions back at the level where entry occurred. Table 4.13 shows that emission reduction levels between 33.3 and 36.72 can be attained with two different relative standards. As mentioned before, in this case, the government has to make a choice which relative standard it will use to achieve the desired emission reduction level. To maximize welfare, the government should choose the level that gives the highest number of firms since this increases total output and diminishes market power.

Combining the two emissions trading schemes leads in all cases to a stimulation of the sector with the highest quota price at the expense of the other sector. In most cases, this means that the credit sector is stimulated. Only in Table 4.12 for emission reduction levels of 40% to 80% is the permit sector stimulated since here the permit price is higher than the credit price.

One of the unresolved issues is which instrument leads to highest welfare. As a glance at Tables 4.7-4.12 shows, in most cases, permit trading leads to higher welfare than credit trading. Only in a few cases does credit trading lead to higher welfare. These cases are given in Table 4.8 for $b = 1$, Table 4.9 for emission reduction levels of 80 and 90%, and in Table 4.12 for emission reduction levels of 10, 20, 30 and 90%. It is worth noting that these are all cases where marginal abatement costs are either low or high. At these levels, the differences in abatement costs between permit trading and credit trading are less pronounced and the additional production under credit trading has a larger impact on welfare than the increase in abatement cost under this scheme.

Combining the two schemes can lead to both an increase or a decrease in welfare. Increases in welfare are shown in Table 4.7 for $b = 6$ to $b = 50$, Table 4.8 for $b = 1$ and for $b = 9$ and in Table 4.12 for emission reduction levels of 30-90%. In Table 4.7 the increase in welfare comes from the large saving in abatement costs as a result of combining the schemes. As is clear from Table 4.7, there is a large difference between the permit and the credit price, while the quota price under combined trading is quite close to the permit price in the separate scheme. In Table 4.12 it should be remembered that here combined trading stimulates the permit sector for emission reduction levels of 40% to 80%. So here, welfare increases because the permit sector is stimulated as a result of combining the two schemes.

4.4 Conclusions

This chapter has analyzed and compared two types of emissions trading to see whether they function similarly or differently under two market structures: perfect and imperfect competition. The first type is permit trading, which is emissions trading based on an absolute cap on emissions, while credit trading is based on relative caps on emissions. Credit trading works similar to an emissions tax combined with an output subsidy. The major general result is that credit trading leads to higher total output than permit trading. The explanation for that phenomenon is that in the credit trading scheme, firm output is subsidized by allowing additional emissions, whereas in a permit trading scheme, additional output requires either extra abatement costs or purchase of permits. This result holds under both perfect and imperfect competition. However, in other respects, the effect of the two schemes may be rather different under perfect and imperfect competition.

The general model shows that under perfect competition, credit trading always leads to higher abatement costs than permit trading. This is the consequence of the higher level of output in the credit trading sector, which requires higher abatement costs per unit of output compared to the sector with permit trading. Since marginal abatement costs are higher in the credit trading sector, the price of credits is higher than the price of permits. The implicit subsidization of output in the credit scheme has consequences for welfare. Since firms get extra credits for free when increasing output, total output in the credit sector is too high. At the margin of production, marginal benefits to the consumer are lower than the actual marginal cost of production. This implies that the marginal abatement costs are not included fully in the market price of output. The combination of too high output and too high marginal abatement costs makes credit trading an inferior instrument compared with permit trading.

The two schemes can be combined by allowing the use of credits to cover emissions in the permit sector and vice versa. Emissions trading will lead to a uniform price in the two sectors, lowering the price of credits, while raising the price of permits. The lower abatement costs stimulate output in the credit sector, increasing the sector's emissions while the higher abatement costs reduce output and emissions in the permit sector. Consequently, the discrepancy in terms of output and abatement effort between the two sectors will increase by allowing emission trading between them, making the welfare loss due to overproduction in the credit sector still larger. However, there is also a positive welfare effect. The sale of emission allowances from firms in the permit sector to firms in the credit sector makes that abatement increases in the permit sector where marginal abatement costs are relatively low, whereas abatement decreases in the credit sector, where marginal abatement costs are relatively high. The result is that total abatement costs go down. The savings on total abatement costs can exceed the welfare loss due to higher production in the credit sector. This is most likely to be the case when marginal abatement costs rise sharply and price elasticity of output demand is low. In the reverse case, welfare will decrease. In the simulations, it was shown that the general conclusions do not always hold when the number of firms is taken to be an integer value. Hence, general models will give too simplified a view on the problem.

Under imperfect competition, it still holds that under separate schemes, the credit sector has higher output at lower output price, higher marginal abatement costs and a higher price for emission allowances than the permit sector. Combining the two sectors also has the same impact of equalizing the price of emission allowances and increasing the discrepancy in sector outputs and emissions. Mainly, the welfare impacts are different. In the case of imperfect competition, output is below the welfare maximizing level. Here the stimulus credit trading gives to output, which is missing in the permit trading scheme, counteracts the output distortion caused by the structure of the market. The positive welfare effect may be such that a credit trading scheme performs better on welfare than a permit scheme. If the separate sectors are linked and the discrepancies in output increase, they may have a positive impact on welfare (which it never has under perfect competition), thus supporting the positive effect of lower abatement costs.

However, the above general conclusions on imperfect competition are subject to the proviso that the full mathematical proof of the above relations have only been derived for the case where the credit and permit schemes have the same number of firms. For the likely case where there are more firms in the credit sector than in the permit sector, the formal proof could not be given and we had to rely on simulations. In all, except one, specific ranges of simulations, the above general conclusions are confirmed for the case where credit trading leads to a higher number of firms in the industry than permit trading. The exception is the case where with separate markets, the permit price is higher than the credit price. The anomaly seems to reflect the impact of entry and exit of firms when there are few incumbents.

The major message of this chapter for policy makers is that under imperfect competition, one cannot in general say that credit trading is an inefficient instrument.

In this chapter, we have assumed that governments set their instrument such that an absolute limit on emissions is reached. This may be unrealistic, especially for the case of relative standards and credit trading, since the government may have too little information to set the standard correctly. An issue that would warrant further research is how the instruments work when firms are heterogeneous. In this chapter, firms are homogeneous and therefore, there is no trading in the separate schemes.

4.A Comparative Statics for Perfect Competition

In this Appendix, the effects on output per firm q, emission level per firm E, product price p and number of firms n of a change in the total limit on emissions L will be derived. Assuming a change from a non-binding limit to a limit that is just binding will allow us to analyze the effect of the introduction of regulation.

4.A.1 Permit Trading

Short Run

In the short run, the following conditions must hold under permit trading

$$p = C_q \tag{4.39}$$

$$-C_E = R^p \tag{4.40}$$

$$p = p(nq) \tag{4.41}$$

Differentiating equations (4.39)-(4.41) totally with respect to E gives

$$\frac{dp}{dE} - C_{qE} - C_{qq}\frac{dq}{dE} = 0 \tag{4.42}$$

$$-C_{EE} - C_{qE}\frac{dq}{dE} = \frac{dR}{dE} \tag{4.43}$$

$$\frac{dp}{dE} = np'\,\frac{dq}{dE} \tag{4.44}$$

The result is

$$\frac{dq^p}{dE} = \frac{C_{qE}}{np' - C_{qq}} > 0 \tag{4.45}$$

$$\frac{dR^p}{dE} = -\left(\frac{np'C_{EE} + {C_{qE}}^2 - C_{EE}C_{qq}}{np' - C_{qq}}\right) < 0 \tag{4.46}$$

$$\frac{dp^p}{dE} = \frac{np'C_{qE}}{np' - C_{qq}} < 0 \tag{4.47}$$

The signs of equations (4.45)-(4.47) follow from the assumptions on the cost function and condition (4.59).

Long Run

In the long run, we need that (4.39)-(4.41) and the two following conditions hold

$$pq = C(q,E) + R^p E \tag{4.48}$$

$$nE = L \tag{4.49}$$

Furthermore, the second order condition is

$$\mathbf{C_{xx}} = \begin{pmatrix} C_{qq} & C_{Eq} \\ C_{qE} & C_{EE} \end{pmatrix} \quad \text{is positive semidefinite} \tag{4.50}$$

Differentiating (4.39)-(4.41), (4.48) and (4.49) totally with respect to L gives

$$\frac{dp}{dL} - C_{qE}\frac{dE}{dL} - C_{qq}\frac{dq}{dL} = 0$$

$$q\frac{dp}{dL} = E\frac{dR}{dL}$$

$$\frac{dR}{dL} = -C_{Eq}\frac{dq}{dL} - C_{EE}\frac{dE}{dL} \tag{4.51}$$

$$E\frac{dn}{dL} + n\frac{dE}{dL} = 1 \tag{4.52}$$

$$\frac{dp}{dL} = p'\left(q\frac{dn}{dL} + n\frac{dq}{dL}\right) \tag{4.53}$$

From these we find the following

$$\frac{dq^p}{dL} = \frac{-qp'\left(EC_{EE} + qC_{qE}\right)}{np'\left(E^2C_{EE} + 2qEC_{qE} + q^2C_{qq}\right) + E^2\left(C_{qE}^2 - C_{EE}C_{qq}\right)} > 0 \tag{4.54}$$

$$\frac{dE^p}{dL} = \frac{qp'\left(EC_{qE} + qC_{qq}\right)}{np'\left(E^2C_{EE} + 2qEC_{qE} + q^2C_{qq}\right) + E^2\left(C_{qE}^2 - C_{EE}C_{qq}\right)} > 0 \tag{4.55}$$

$$\frac{dR^p}{dL} = \frac{q^2 p' \left({C_{qE}}^2 - C_{EE}C_{qq}\right)}{np' \left(E^2 C_{EE} + 2qEC_{qE} + q^2 C_{qq}\right) + E^2 \left({C_{qE}}^2 - C_{EE}C_{qq}\right)} < 0 \tag{4.56}$$

$$\frac{dp^p}{dL} = \frac{qEp' \left(C_{qE}^2 - C_{EE}C_{qq}\right)}{np' \left(E^2 C_{EE} + 2qEC_{qE} + q^2 C_{qq}\right) + E^2 \left(C_{qE}^2 - C_{EE}C_{qq}\right)} < 0 \tag{4.57}$$

$$\frac{dn^p}{dL} = \frac{np' \left(EC_{EE} + qC_{qE}\right) + E \left(C_{qE}^2 - C_{EE}C_{qq}\right)}{np' \left(E^2 C_{EE} + 2qEC_{qE} + q^2 C_{qq}\right) + E^2 \left(C_{qE}^2 - C_{EE}C_{qq}\right)} \tag{4.58}$$

The signs for the different equations are found through conditions

$$C_{qq}C_{EE} - C_{qE}^2 \geq 0 \tag{4.59}$$

$$H \equiv q^2 C_{qq} + 2qEC_{qE} + E^2 C_{EE} \geq 0 \tag{4.60}$$

$$qC_{qq} + EC_{qE} > 0 \tag{4.61}$$

$$qC_{qE} + EC_{EE} < 0 \tag{4.62}$$

Conditions (4.59) and (4.60) follow from the second order condition given in (4.50). The LHS of (4.59) is the determinant of (4.50) and must be non-negative. Condition (4.60) follows from the fact that $\mathbf{hC_{xx}h'} \geq 0$ for any vector $\mathbf{h}$. In this case, $\mathbf{h} = (q \quad E)$. Condition (4.61) is required to guarantee monotonicity with credit trading. By monotonicity we mean that industry emissions should decline when L decreases (see Dijkstra (1999) p. 80 for a discussion). Condition (4.62) ensures that under credit trading product price decreases with emissions.

It is clear from (4.60) and (4.59) that the denominator of (4.54)-(4.58) is negative. It can then be easily established that $\frac{dq^p}{dL} > 0$, $\frac{dE^p}{dL} > 0$, $\frac{dR^p}{dL} < 0$ and $\frac{dp^p}{dL} \leq 0$. However, $\frac{dn^p}{dL}$ can either be positive or negative, as the first term in the nominator is positive and the second term is negative. Note however that if $p' = 0$, $\frac{dn^p}{dL} > 0$, implying that as the emissions limit decreases, the number of firms will decrease when demand is infinitely elastic. On the other hand, when $p' \to -\infty$, $\frac{dn^p}{dL} < 0$, implying that when demand is totally inelastic the number of firms will increase when the emission limit decreases.

4.A.2 Credit Trading

Short Run

For credit trading, the following conditions must hold in the short run

$$p = C_q - R^c \frac{E}{q} \tag{4.63}$$

$$-C_E = R^c \tag{4.64}$$

$$p = p(nq) \tag{4.65}$$

Differentiating these with respect to E gives

$$C_E + E\left(C_{EE} + \frac{dq}{dE}C_{qE}\right) = \frac{E}{q}\frac{dq}{dE}C_E + q\left(\frac{dp}{dE} - C_{qE} - \frac{dq}{dE}C_{qq}\right)$$

and (4.43) and (4.44). The solution then is

$$\frac{dq^c}{dE} = \frac{q\left(C_E + EC_{EE} + qC_{qE}\right)}{EC_E + q^2np' - q\left(EC_{qE} + qC_{qq}\right)} > 0 \tag{4.66}$$

$$\frac{dR^c}{dE} = -\left(\frac{C_E\left(EC_{EE} + qC_{qE}\right) + nq^2p'C_{EE} + q^2\left({C_{qE}}^2 - C_{EE}C_{qq}\right)}{EC_E + q^2np' - q\left(EC_{qE} + qC_{qq}\right)}\right) \tag{4.67}$$

$$\frac{dp^c}{dE} = \frac{nqp'\left(C_E + EC_{EE} + qC_{qE}\right)}{EC_E + q^2np' - q\left(EC_{qE} + qC_{qq}\right)} < 0 \tag{4.68}$$

The denominators in (4.66)-(4.68) are negative because of (4.61). The signs of (4.66) and (4.68) then follow from (4.62). The sign of dR^c/dE is ambiguous. However, when going from no regulation (where $C_E = 0$) to regulation, $dR^c/dE < 0$.

Combined Trading For combined trading, the comparative statics change somewhat. Above, we analyzed the effect of a change in total emissions through a change in the emission standard $\bar{e}$. Now, total emissions in the credit sector change through an influx of quotas. As a result, total output in the credit sector rises. Then the emission standard has to be tightened, so that without the extra quotas, total emissions would be equal to the initial industry ceiling M:

$$\bar{e} = \frac{M}{nq} \tag{4.69}$$

We still need (4.63)-(4.65). Differentiating these with respect to E and using (4.69) gives

$$Mq\left(C_{EE} + q'C_{qE}\right) = Mq'C_E + nq^2\left(p' - C_{qE} - q'C_{qq}\right)$$

and (4.40) and (4.41). The solution then is

$$\frac{dq^c}{dL} = \frac{q\left(\bar{e}C_{EE} + C_{qE}\right)}{\bar{e}C_E + qnp' - q\left(\bar{e}C_{qE} + C_{qq}\right)} > 0 \tag{4.70}$$

$$\frac{dR^c}{dL} = -\left(\frac{\bar{e}C_E C_{EE} + q\left(np'C_{EE} + {C_{qE}}^2 - C_{EE}C_{qq}\right)}{\bar{e}C_E + qnp' - q\left(\bar{e}C_{qE} + C_{qq}\right)}\right) < 0 \tag{4.71}$$

$$\frac{dp^c}{dL} = \frac{nqp'\left(\bar{e}C_{EE} + C_{qE}\right)}{\bar{e}C_E + qnp' - q\left(\bar{e}C_{qE} + C_{qq}\right)} < 0 \tag{4.72}$$

The denominators are negative by the fact that $\bar{e} < E/q$ and (4.61). The signs of (4.70) and (4.72) follow from (4.62) and the sign of (4.71) follows from (4.59).

Long Run

In the long run, (4.63)-(4.65) and the following conditions must hold

$$pq = C(q, E) \tag{4.73}$$

$$nE = L \tag{4.74}$$

The second order condition is given by (4.50).

Differentiating (4.63)-(4.65) and (4.73)-(4.74) totally gives

$$-\frac{dp}{dL}+\left(C_{qq}-\frac{E}{q^2}C_E+\frac{E}{q}C_{qE}\right)\frac{dq}{dL}+\left(C_{qE}+\frac{1}{q}C_E+\frac{E}{q}C_{EE}\right)\frac{dE}{dL}=0$$

$$q\frac{dp}{dL}=C_E\frac{dE}{dL}+C_q\frac{dq}{dL}$$

And (4.51)-(4.53).

From these, one can derive the following

$$\frac{dq^c}{dL}=\frac{-q^3p'\left(EC_{EE}+qC_{qE}\right)}{\left(nq^2p'+EC_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}>0 \tag{4.75}$$

$$\frac{dE^c}{dL}=\frac{q^3\,p'\,\left(EC_{qE}+qC_{qq}\right)}{\left(nq^2p'+EC_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}>0 \tag{4.76}$$

$$\frac{dR^c}{dL}=\frac{q^4p'\left({C_{qE}}^2-C_{EE}C_{qq}\right)}{\left(nq^2p'+EC_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}<0 \tag{4.77}$$

$$\frac{dp^c}{dL}=\frac{\left(q\,p'\,C_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}{\left(n\,q^2\,p'+E\,C_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}<0 \tag{4.78}$$

$$\frac{dn^c}{dL}=\frac{nq^2p'\left(EC_{EE}+qC_{qE}\right)+C_E\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)}{\left(nq^2p'+EC_E\right)\left(E^2C_{EE}+2qEC_{qE}+q^2C_{qq}\right)} \tag{4.79}$$

Using conditions (4.59) to (4.62), it is clear that the denominator of (4.75)-(4.79) is negative. It can then be established that $\frac{dq^c}{dL}>0$, $\frac{dE^c}{dL}>0$, $\frac{dR}{dL}<0$ and $\frac{dp^c}{dL}\leq 0$. However, as with permit trading, the sign of $\frac{dn^c}{dL}$ is not immediately clear since the first term in parenthesis in the nominator is negative, while the second term in parenthesis is positive. Hence, the number of firms can both increase or decrease as a result of regulation. However, as with permit trading, $\frac{dn}{dL}>0$ for $p'=0$ and $\frac{dn}{dL}<0$ for $p'\rightarrow-\infty$. This implies that when demand is infinitely elastic the number of firms will decrease as the emissions limit decreases and that when demand is totally inelastic the number of firms will increase when the emission limit decreases.

Combined Trading

For the credit sector under combined trading, we still need conditions (4.63)-(4.65) and (4.74) to hold, but the zero-profit condition changes to

$$pq = C(q,E) + R^c(E - \bar{e}q) \tag{4.80}$$

Furthermore, $\bar{e}$ is now given by (4.69). Differentiating (4.63)-(4.65), (4.73) and (4.80) with respect to L, using (4.69) gives

$$nqM\frac{dR}{dL} = -Mq\frac{dn}{dL}C_E - Mn\frac{dq}{dL}C_E + n^2q^2\left(-\frac{dp}{dL} + \frac{dE}{dL}C_{qE} + \frac{dq}{dL}C_{qq}\right)$$

$$-E\left(C_{Eq}\frac{dq}{dL} + C_{EE}\frac{dE}{dL}\right) = q\left(C_{qE}\frac{dE}{dL} + C_{qq}\frac{dq}{dL}\right)$$

And (4.51)-(4.53). The solution is

$$\frac{dq}{dL} = -\left(q\,\left(n^2\,q^2\,p' + M\,C_E\right)\,\left(E\,C_{EE} + q\,C_{qE}\right)\right)/D > 0 \tag{4.81}$$

$$\frac{dE}{dL} = \left(q\,\left(n^2\,q^2\,p' + M\,C_E\right)\,\left(E\,C_{qE} + q\,C_{qq}\right)\right)/D > 0 \tag{4.82}$$

$$\frac{dR^c}{dL} = \left(q^2\,\left(n^2\,q^2\,p' + M\,C_E\right)\,\left({C_{qE}}^2 - C_{EE}\,C_{qq}\right)\right)/D < 0 \tag{4.83}$$

$$\frac{dp}{dL} = -\left(nq^3\,\left(M - n\,E\right)\,p'\,\left({C_{qE}}^2 - C_{EE}\,C_{qq}\right)\right)/D < 0 \tag{4.84}$$

$$\begin{aligned}\frac{dn}{dL} = &\Big[n\left(n^2\,q^2\,p' + M\,C_E\right)\,\left(E\,C_{EE} + q\,C_{qE}\right)\\ &+ nq^2\,\left(M - n\,E\right)\,\left(C_{EE}\,C_{qq} - {C_{qE}}^2\right)\Big]/D\end{aligned} \tag{4.85}$$

Where

$$
\begin{aligned}
D =n \Big[& \left(n^2 \, q^2 \, p' + M C_E\right) \, \left(E^2 \, C_{EE} + 2 \, q \, E \, C_{qE} + q^2 \, C_{qq}\right) \\
& + q \, E^2 \, (M - n \, E) \, \left(C_{EE} \, C_{qq} - {C_{qE}}^2\right) \Big] < 0
\end{aligned}
\tag{4.86}
$$

To determine the sign of (4.81)-(4.86) we need conditions (4.59)-(4.62). D is negative from $M < nE$, (4.59) and (4.60). dq/dL and dE/dL are positive by (4.61) and (4.62). dR/dL and dp/dL are negative by (4.59) and $M < nE$. The sign of dn/dL is ambiguous.

To find out whether combined trading leads to higher or lower welfare in the short run, we need to know the sign and size of $\frac{E}{q}\frac{dq}{dE} - \frac{dE}{dL}$. From (4.81) and (4.82) we find

$$
\frac{E}{q}\frac{dq}{dE} - \frac{dE}{dL} = -\left[n^2 q^2 p' + M C_E\right) \left(E^2 C_{EE} + 2qEC_{qE} + q^2 C_{qq}\right] /D
$$

This shows that $-\frac{1}{n} < \frac{E}{q}\frac{dq}{dE} - \frac{dE}{dL} < 0$

4.B Comparative Statics for Imperfect Competition

4.B.1 Short run

Permit trading

In the short run, the following conditions must hold for permit trading

$$
\begin{aligned}
p + p'q &= C_q && (4.87)\\
-C_E &= R && (4.88)\\
p &= p(nq) && (4.89)
\end{aligned}
$$

For the comparative statics we differentiate (4.87) to (4.89) totally with respect to E:

$$
\begin{aligned}
\frac{dp}{dE} + p''n\frac{dq}{dE} + p'\frac{dq}{dE} &= C_{qq}\frac{dq}{dE} + C_{qE} \\
\frac{dR}{dE} &= -C_{EE} - C_{qE}\frac{dq}{dE} && (4.90) \\
\frac{dp}{dE} &= np'\frac{dq}{dE} && (4.91)
\end{aligned}
$$

Defining[1]

$$V \equiv C_{EE}\left(C_{qq} - p''q - 2p'\right) - C_{qE}^2 > 0 \tag{4.92}$$

$$Z \equiv -\left(qp'' + p'\right) > 0 \tag{4.93}$$

the solution is:

$$
\begin{aligned}
\frac{dq^p}{dE} &= \frac{C_{qE}}{(n-1)(qp''+p') + (qp''+2p'-C_{qq})} > 0 && (4.94) \\
\frac{dR^p}{dE} &= \frac{V + [(n-1)C_{EE}Z]}{(n-1)(qp''+p') + (qp''+2p'-C_{qq})} < 0 && (4.95) \\
\frac{dp^p}{dE} &= \frac{np'C_{qE}}{(n-1)(qp''+p') + (qp''+2p'-C_{qq})} < 0 && (4.96)
\end{aligned}
$$

The denominators on the RHS are negative by (4.25) and $C_{qq} > 0$. So in the short run, a tightening of environmental policy leads to lower output, a higher permit price and a higher product price.

Credit trading

In the short run, the following conditions must hold for credit trading

$$p + p'q = C_q - \bar{e}R \tag{4.97}$$

and (4.88) and (4.89).

For the comparative statics, differentiate (4.97), (4.88) and (4.89) totally

[1]The inequalities follow from (4.62) and (4.25).

with respect to E. This gives:

$$\frac{dp}{dE}+qp''n\frac{dq}{dE}+p'\frac{dq}{dE}=C_{qq}\frac{dq}{dE}+C_{qE}+C_E\left(\frac{1}{q}-\frac{E}{q^2}\frac{dq}{dE}\right)+\frac{E}{q}C_{EE}+\frac{E}{q}C_{qE}\frac{dq}{dE}$$

and (4.90) and (4.91). The solution is

$$\frac{dq^c}{dE} = \frac{C_E+qC_{qE}+EC_{EE}}{q(nqp''+(n+1)p')+\frac{E}{q}C_E-[qC_{qq}+EC_{qE}]}>0 \quad (4.98)$$

$$\frac{dR^c}{dE} = \frac{qV+q(n-1)C_{EE}Z-C_E\left[\frac{E}{q}C_{EE}+C_{qE}\right]}{q(nqp''+(n+1)p')+\frac{E}{q}C_E-[qC_{qq}+EC_{qE}]} \quad (4.99)$$

$$\frac{dp^c}{dE} = \frac{np'\left[C_E+qC_{qE}+EC_{EE}\right]}{q(nqp''+(n+1)p')+\frac{E}{q}C_E-[qC_{qq}+EC_{qE}]}<0 \quad (4.100)$$

with $V>0$ given by (4.92) and $Z>0$ by (4.93). The denominators are negative by (4.25) and (4.61). The numerators are negative in (4.98) and positive in (4.100) by (4.62) and (4.25). The sign of the numerator in (4.99) is ambiguous. Note however that when environmental policy goes from non-binding to binding, $C_E=0$ and (4.99) is negative. So under credit trading, a tightening of environmental policy will lead to lower firm and industry production, while the credit price may increase or decrease. However, initially, when environmental policy becomes binding, the credit price will rise.

Combined Trading

Under combined trading, (4.88), (4.89) and (4.97) still need to hold for the credit sector. However, $\bar{e}$ is now given by $\bar{e}=M/(n^cq^c)$. Differentiating (4.88), (4.89) and (4.97) totally with respect to E gives

$$\frac{dp}{dE}+qp''n\frac{dq}{dE}+p'\frac{dq}{dE}=C_{qq}\frac{dq}{dE}+C_{qE}+\frac{M}{nq^2}C_E\frac{dq}{dE}+\frac{M}{nq}\left(C_{EE}+C_{qE}\frac{dq}{dE}\right)$$

and (4.90) and (4.91). The solution is

$$\frac{dq^c}{dE}=\frac{nqC_{qE}+MC_{EE}}{nq\left(nqp''+(n+1)p'\right)+\frac{M}{q}C_E-(nqC_{qq}+MC_{qE})}>0 \quad (4.101)$$

$$\frac{dR^c}{dE} = \frac{nqV - nq(n-1)C_{EE}\,(qp'' + p') - \frac{M}{q}C_E C_{EE}}{nq\,(nqp'' + (n+1)p') + \frac{M}{q}C_E - (nqC_{qq} + MC_{qE})} < 0 \qquad (4.102)$$

$$\frac{dp^c}{dE} = \frac{np'\,(nqC_{qE} + MC_{EE})}{nq\,(nqp'' + (n+1)p') + \frac{M}{q}C_E - (nqC_{qq} + MC_{qE})} < 0 \qquad (4.103)$$

with $V > 0$ given by (4.92) and $M < nE$. The denominators are negative by (4.25) and (4.61). The numerators are positive in (4.101) and negative in (4.103) by (4.62) and (4.25). The numerator in (4.102) is negative by (4.92) and (4.25).

4.B.2 Long run

Unlike the case with perfect competition, the number of firms now does not change continuously as environmental policy becomes stricter and stricter. The strictness of environmental policy will affect the firms' profits. If profits decrease, a firm will leave the industry just before profits turn into losses, thereby restoring profitability for the remaining firms. If profits increase, this might attract another firm to the industry, which will reduce profits for each firm. In subsection B.2.1, we will derive the comparative statics for the case where the number of firms remains constant. In subsection B.2.2, we analyze the effects of a change in the number of firms.

Constant number of firms

Permit trading. The comparative statics for permit trading are the same as for the short run. We only need to determine the effect on profits. From (4.23) and (4.88), profits can be written as:

$$\pi = pq - C(q, E) + EC_E \qquad (4.104)$$

Then for permit trading, differentiating with respect to E and substituting (4.87) gives

$$\frac{d\pi}{dE} = q\frac{dP}{dE} - p'q\frac{dq}{dE} + EC_{EE} + EC_{qE}\frac{dq}{dE}$$

Defining:[2]

$$Y \equiv C_{qq}C_{EE} - C_{qE}^2 \geq 0 \tag{4.105}$$

and substituting (4.94) and (4.96) then gives :

$$\frac{d\pi^p}{dE} = \frac{\left[qC_{qE} + EC_{EE}\right](n-1)p' - EY + EC_{EE}(np'' + 2p')}{(n-1)(qp'' + p') + (qp'' + 2p' - C_{qq})}$$

The denominator on the RHS is negative by (4.25). The sign of the numerator is ambiguous, since all terms are positive by (4.62), (4.105) and (4.25).

Thus, the effect of the strictness of environmental policy on profits, and thereby on the entry or exit of firms, is ambiguous.

Credit trading. The first order condition with respect to q now becomes:

$$p + p'q = C_q - \left(\frac{n-1}{n}\right)\bar{e}R \tag{4.106}$$

The first order condition with respect to E is still (4.88).

For the comparative statics, differentiate (4.106), (4.88) and (4.89) totally with respect to E:

$$\frac{dp}{dE} + qp''n\frac{dq}{dE} + p'\frac{dq}{dE} =$$
$$= C_{qq}\frac{dq}{dE} + C_{qE} + \left[\frac{n-1}{n}\right]\left[C_E\left(\frac{1}{q} - \frac{E}{q^2}\frac{dq}{dE}\right) + \frac{E}{q}C_{EE} + \frac{E}{q}C_{qE}\frac{dq}{dE}\right]$$

and (4.90) and (4.91). Defining:[3]

$$F \equiv q\left((n+1)p' + nqp''\right) + \frac{n-1}{n}\frac{E}{q}C_E - \left[qC_{qq} + \frac{n-1}{n}EC_{qE}\right] < 0 \tag{4.107}$$

[2]The inequality follows from (4.59).
[3]The inequality follows from (4.25) and (4.61).

the solution is:

$$
\begin{aligned}
\frac{dq}{dE} &= \left(\frac{n-1}{n}C_E + \frac{n-1}{n}EC_{EE} + qC_{qE}\right)/F > 0 && (4.108)\\
\frac{dR}{dE} &= \Big[q\left(C_{EE}\left(C_{qq} - p''q - 2p'\right) - C_{qE}^2\right) + q(n-1)C_{EE}Z \\
&\qquad -\frac{n-1}{n}C_E\left(\frac{E}{q}C_{EE} + C_{qE}\right) - 2EC_{EE}C_{qE}\Big]/F && (4.109)\\
\frac{dp}{dE} &= np'\left[\frac{n-1}{n}C_E + \frac{n-1}{n}EC_{EE} + qC_{qE}\right]/F < 0 && (4.110)
\end{aligned}
$$

with $V > 0$ given by (4.92) and $Z > 0$ by (4.93). The numerator is negative in (4.108) and positive in (4.110) by (4.62). The sign of (4.109) is ambiguous. The result is basically the same as in the short run. A tightening of environmental policy leads to lower firm and industry output, while the credit price may increase or decrease. Note however that when environmental policy is tightened from non-binding to binding, the credit price will increase since in that case $C_E = 0$.

In the long run, profits under credit trading are given by

$$\pi = pq - C(q, E) \tag{4.111}$$

Differentiating with respect to E using (4.106) gives

$$\frac{d\pi}{dE} = q\frac{dp}{dE} + \frac{dq}{dE}\left(\frac{n-1}{n}\frac{E}{q}C_E - p'q\right) - C_E$$

Substituting from (4.108) and (4.110) gives

$$
\begin{aligned}
\frac{d\pi}{dE} = \Big[&\left((n-1)qp' + \frac{n-1}{n}\frac{E}{q}C_E\right) \\
&\left(\frac{n-1}{n}C_E + \frac{n-1}{n}EC_{EE} + qC_{qE}\right) - F\,C_E\Big]\Big/F
\end{aligned}
\tag{4.112}
$$

where $F < 0$ is given by (4.107). The sign of the nominator on the RHS of (4.112) is ambiguous since the first term is positive by (4.62) and $-F\,C_E$ is positive. Thus, the effect of the strictness of environmental policy on profits, and thereby on the entry or exit of firms, is ambiguous.

Combined trading. Under combined trading, the comparative statics for the credit sector are somewhat different than the analysis given above for credit trading. Specifically, $\bar{e}$ is now given by $\bar{e} = M/(n^c q^c)$. For the comparative statics we differentiate (4.106), (4.88) and (4.89) totally with respect to E:

$$\frac{dp}{dE}+\frac{dq}{dE}\left(p' + n\,q\,p''\right) = C_{qE} + \frac{M}{nq}\left(\frac{n-1}{n}\right)\left[\left(C_{qE} - \frac{1}{q}C_E\right)\frac{dq}{dE} + C_{EE}\right] + \frac{dq}{dE}\,C_{qq}$$

and (4.90) and (4.91). Defining:[4]

$$S \equiv nq\left((n+1)\,p' + nqp''\right) + \bar{e}\,(n-1)\,C_E - \left(\frac{M}{n}\,(n-1)\,C_{qE} + nqC_{qq}\right) < 0 \tag{4.113}$$

the solution is:

$$\frac{dq}{dE} = \left[\frac{M}{n}\,(n-1)\;C_{EE} + n\,q\,C_{qE}\right]/S > 0 \tag{4.114}$$

$$\frac{dR}{dE} = \left[nq\left(C_{EE}\left(C_{qq} - (n+1)p' - nqp''\right) - C_{qE}^2\right) - \bar{e}(n+1)C_E C_{EE}\right]/S < 0 \tag{4.115}$$

$$\frac{dp}{dE} = n\,p'\left(\frac{M}{n}\,(n-1)\;C_{EE} + n\,q\,C_{qE}\right)/S < 0 \tag{4.116}$$

The signs of the numerators follow from (4.62) for (4.114) and (4.116) and from (4.92) for (4.115).

Differentiating profits in (4.104) with respect to E, using (4.106), (4.114)

[4] The inequality follows from (4.25) and (4.61).

and (4.116) gives

$$\frac{d\pi}{dE} = \Bigg[n^2qp' \left(\frac{M}{n}(n-1)C_{EE} + nqC_{qE} \right) + n^2qEC_{EE}\left((n+1)p' + nqp''\right)$$
$$+ (n-1)\bar{e}C_E \left((n-1)\frac{M}{n}C_{EE} + nqC_{qE} \right) + \bar{e}(n-1)nEC_EC_{EE}$$
$$- n^2qEY - p'q\left(M(n-1)C_{EE} + n^2qC_{qE}\right) \Bigg] \Big/ S \tag{4.117}$$

where $S < 0$ is given (4.113). The sign of (4.117) is ambiguous which follows from (4.62), (4.59), (4.60) and (4.25).

Therefore, in all cases, it is ambiguous in general whether profits, and by implication the number of firms, increase or decrease as environmental policy is tightened.

A change in the number of firms

Permit trading. Differentiate (4.87)-(4.89) totally with respect to n:

$$\frac{dp}{dn} + p''q\left(q + n\frac{dq}{dn}\right) + p'\frac{dq}{dn} = C_{qq}\frac{dq}{dn} - C_{qE}\frac{L}{n^2} \tag{4.118}$$
$$\frac{dR}{dn} = -C_{qE}\frac{dq}{dn} + C_{EE}\frac{L}{n^2} \tag{4.119}$$
$$\frac{dp}{dn} = p'\left(q + n\frac{dq}{dn}\right) \tag{4.120}$$

The solution is:

$$\frac{dq^p}{dn} = \frac{EC_{qE} + nq(p' + qp'')}{nC_{qq} - n(n+1)p' - n^2qp''} < 0 \tag{4.121}$$
$$\frac{dR^p}{dn} = \frac{EV + Z\left[nqC_{qE} + (n-1)EC_{EE}\right]}{nC_{qq} - n(n+1)p' - n^2qp''} \tag{4.122}$$
$$\frac{dp^p}{dn} = \frac{p'\left[qC_{qq} + EC_{qE} - p'q\right]}{C_{qq} - (n+1)p' - nqp''} < 0 \tag{4.123}$$

with $V > 0$ given by (4.92) and $Z > 0$ by (4.93). The denominator is positive by (4.25). The numerators in (4.121) and (4.123) are negative by

(4.25). The sign of (4.122) is ambiguous. So an increase in the number of firms will under permit trading lead to lower firm output, but higher industry output. The permit price may either increase or decrease as a result of the higher number of firms.

To see what happens to profits as n changes, write profits in (4.104) as

$$\pi = pq - C\left[q, L/n\right] - RL/n \tag{4.124}$$

and differentiate with respect to n:

$$\frac{d\pi}{dn} = \frac{dp}{dn}q + p\frac{dq}{dn} - C_q\frac{dq}{dn} - \frac{L}{n}\frac{dR}{dn}$$

Substituting (4.121) to (4.123) and (4.87) yields:

$$\begin{aligned}\frac{d\pi^p}{dn} = \Big(& np'H - E^2Y - nq^2p'\left[2p' + qp''\right] + p'E\left[EC_{EE} - qC_{qE}\right] \\ & + nqp''E\left[EC_{EE} + qC_{qE}\right]\Big)\Big/ G\end{aligned} \tag{4.125}$$

Where

$$G = nC_{qq} - n(n+1)p' - n^2qp''$$

The sign of (4.125) is ambiguous. Hence, under permit trading, profits may rise or fall with an increase in the number of firms. However, when $p'' \geq 0$, (4.125) is negative, so that in that case, an increase in the number of firms always leads to a decrease in profits. This is the case given in the simulations and the results given in Tables 4.7-4.12 confirm this outcome.

Credit trading. Differentiating (4.106), (4.88) and (4.89) totally with respect to n, we find:

$$\begin{aligned}\frac{dp}{dn} + p''q\left[n\frac{dq}{dn} + q\right] + p'\frac{dq}{dn} &= C_{qq}\frac{dq}{dn} - C_{qE}\frac{L}{n^2} + \frac{1}{n^2}\frac{E}{q}C_E \\ &+ \frac{n-1}{n}\frac{E}{q}\left[-C_E\left(\frac{1}{q}\frac{dq}{dn} + \frac{1}{n}\right) + C_{qE}\frac{dq}{dn} - \frac{E}{n}C_{EE}\right]\end{aligned}$$

and (4.119) and (4.120). Define

$$A \equiv nq\left((n+1)p' + nqp''\right) + (n-1)\frac{E}{q}C_E - [nqC_{qq} + (n-1)EC_{qE}] < 0$$

The sign follows from (4.25) and (4.61). The solution is:

$$\frac{dq}{dn} = \left(\frac{2-n}{n}EC_E - E\left[qC_{qE} + \frac{n-1}{n}EC_{EE}\right] - nq^2\left[p' + qp''\right]\right)/A \tag{4.126}$$

$$\begin{aligned}\frac{dR}{dn} = \Bigg(-E\,q\,Y + \frac{E}{q}C_E\left[\frac{n-2}{n}qC_{qE} + \frac{n-1}{n}EC_{EE}\right]\\ -nq(qC_{qE} + EC_{EE})Z + EqC_{EE}p'\Bigg)/A\end{aligned} \tag{4.127}$$

$$\frac{dp}{dn} = \left(p'\left[-nH + E\left(qC_{qE} + EC_{EE}\right) + nq^2p' + EC_E\right]\right)/A < 0 \tag{4.128}$$

with $Y > 0$ given by (4.105). The numerator in (4.128) is positive by (4.60) and (4.62). The numerators of (4.126) and (4.127) are ambiguous. Hence, as with permit trading, entry leads to higher industry output. However, the effect on firm output and the credit price is ambiguous.

Next, we want to know the effect of a change in the number of firms on profits per firm. Differentiating (4.111) with respect to n, setting $E = L/n$ gives

$$\frac{d\pi^c}{dn} = q\frac{dp}{dn} + \frac{dq}{dn}\left(\frac{n-1}{n}\frac{E}{q}C_E - p'q\right) + C_E\,\frac{L}{n^2} \tag{4.129}$$

Define

$$J \equiv nq\left((n+1)p' + nqp''\right) + (n-1)\frac{E}{q}C_E - [nqC_{qq} + (n-1)EC_{qE}] < 0 \tag{4.130}$$

Substituting (4.126) and (4.128) in (4.129) then gives

$$\begin{aligned}\frac{d\pi^c}{dn} = \Bigg\{ & qp' \left[E\left(qC_{qE} + EC_{EE}\right) + nq^2 p' - nH + EC_E\right] + J\, C_E\, \frac{L}{n^2} \\ & + \left(\frac{n-1}{n}\frac{E}{q}C_E - p'q\right)\left[[\frac{2-n}{n}EC_E \right. \\ & \left. - E\left(qC_{qE} + \frac{n-1}{n}EC_{EE}\right) - nq^2\left[p' + qp''\right]\right]\Bigg\}/J\end{aligned}$$

The sign of the denominator is ambiguous. Hence, also under credit trading, profits may rise or fall with an increase in the number of firms. This result could imply that an increase in the number of firms will lead to an increase in profits. However, in the simulations given in section 3.2, it can be seen that an increase in the number of firms always leads to a decrease in profits.

Combined Trading. We will not present the comparative statics for combined trading. The reason is that the effect of a change in n on both sectors simultaneously would have to be evaluated. The result then is hard to derive and the outcome is likely to be ambiguous. However, Tables 4.7 to 4.12 show that when the number of firms increases, output and emissions per firm decreases, as does the product price and the emissions quota price. For a decrease in the number of firms, we observe the opposite. Note however that in Table 4.9, when the number of firms in the credit sector drops from 4 to 3, the emissions quota price increases. This is probably caused by the simultaneous increase in emission reductions. However, the simulations also show that an increase in the number of firms always leads to a decrease in profits, while the reverse holds for a decrease in the number of firms.

4.C The Simulation Model

4.C.1 Perfect Competition

No Regulation. The situation without regulation is the starting point of the analysis and gives a benchmark for the changes caused by regulation.

Without regulation, profits for a firm are given by

$$\pi = pq - aq^2 - b(q-E)^2 - K$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q-E) = 0 \tag{4.131}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) = 0 \quad \Rightarrow \quad q = E \tag{4.132}$$

Besides these conditions, in the long run there should be no profits:

$$2aq + 2b(q-E) = \frac{aq^2 + b(q-E)^2 + K}{q}$$

Using (4.132) we find

$$q = \sqrt{\frac{K}{a}}$$

Inserting this in (4.131) gives:

$$p = 2\sqrt{aK}$$

Denote by $\tilde{n}$ the number of firms without taking the integer constraint into account. Now, $\tilde{n}$ can be found from the inverse demand function given in (4.38)

$$\tilde{n} = \frac{\alpha\sqrt{\frac{a}{K}} - 2a}{\beta}$$

The equilibrium number of firms is then given by the largest integer less or equal to $\tilde{n}$. Denote the equilibrium values of firm output, product price and number of firms in the no-regulation case by q^0, p^0 and n^0 respectively.

Permit Trading. The initial distribution of permits to incumbent firms is given by

$$\bar{E} = \frac{L}{n^0}$$

The long-run profit maximization problem for the firm is

$$\max_{q,E} \quad \pi = pq - aq^2 - b(q-E)^2 - K - R^p E$$

The first order conditions are given by

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q-E) = 0 \tag{4.133}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) - R^p = 0 \tag{4.134}$$

Two further condition that need to hold in the long-run equilibrium are

$$nE = L \tag{4.135}$$

$$2aq + 2b(q-E) = \frac{aq^2 + b(q-E)^2 + K + R^p\,E}{q} \tag{4.136}$$

Combining equations (4.133)-(4.136) gives the following equation for the equilibrium number of firms $\tilde{n}$

$$\frac{b\,L + \sqrt{K\,\tilde{n}^2(a+b) - a\,b\,L^2}}{\tilde{n}\,(a+b)} = \frac{2\,b\,L + \tilde{n}\,\alpha}{\tilde{n}\;(2\,a + 2\,b + \tilde{n}\,\beta)}$$

The equilibrium $n = n^*$ is then found by rounding down to the nearest integer. Using n^*, q^* can be found through

$$q = \frac{2bL + n\alpha}{n(2a + 2b + n\beta)}$$

After this, the other variables can be found using (4.38) and (4.133)-(4.136).

Credit Trading The relative standard is given by

$$\bar{e} = \frac{L}{nq} = \frac{E}{q}$$

With credit trading, the problem for the firm is

$$\max_{q,E} \quad \pi = pq - aq^2 - b(q-E)^2 - K - R^c(E - \bar{e}q)$$

The first order conditions are

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q-E) + R^c\bar{e} = 0 \tag{4.137}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) - R^c = 0 \tag{4.138}$$

The other conditions that need to hold are that the industry emission ceiling is met and profits are zero, respectively:

$$nE = L \tag{4.139}$$

$$2aq + 2b(q-E) - R^c\bar{e} = \frac{aq^2 + b(q-E)^2 + K + R^c(E - \bar{e}q)}{q} \tag{4.140}$$

In equilibrium, $E = L/n$, and no emissions trading will take place since all firms are identical.

The equilibrium number of firms $\tilde{n}$ can be inferred from

$$\frac{4bL + \tilde{n}\alpha + \sqrt{\tilde{n}\left(\tilde{n}\alpha^2 - 8bL\left(-\alpha + L\beta\right)\right) - 16abL^2}}{2\tilde{n}\left(2a + 2b + \tilde{n}\beta\right)} = \frac{bL + \sqrt{aK\tilde{n}^2(a+b) - abL^2}}{(a+b)\,\tilde{n}}$$

Again, n^* is found by rounding down to the nearest integer. As before, the system can be solved numerically by inserting n^* in the equation for q^*:

$$\frac{4\,b\,L + n\,\alpha + \sqrt{n\,\left(n\,\alpha^2 - 8\,b\,L\,\left(L\,\beta - \alpha\right)\right) - 16\,a\,b\,L^2}}{2\,n\,\left(2\,a + 2\,b + n\,\beta\right)}$$

and then solving for the other variables using equations (4.137)-(4.140).

Combined Trading In the case of combined trading, the condition $nE = L$

for both sectors must be replaced by the following two conditions

$$n^c E^c + n^p E^p = 2L \tag{4.141}$$

$$R^p = R^c = R$$

The first condition merely says that total emissions should be equal to total allowable emissions, while the second condition states that the emission quota prices should be equalized between the two markets.

The number of firms in the permit sector can be found from (4.133), (4.134), (4.136) and (4.38):

$$\tilde{n}^p = \frac{a\,\left(R^2 - 4\,b\,K\right) + (\alpha - R)\,\sqrt{4ab\,(4\,b\,K - R^2)}}{\beta\,\left(4\,b\,K - R^2\right)}$$

For the credit sector, the relative standard is now equal to

$$\bar{e} = \frac{L}{nq} \tag{4.142}$$

Since trading with the permit sector is allowed, emissions E will in general be different from $\bar{e}q$. Then, using (4.137), (4.138), (4.140), (4.142) and (4.38), we find the following for the number of firms:

$$\begin{aligned} \tilde{n}^c = & \frac{1}{\delta\beta}\Big\{-a\,(\delta) - (R-\alpha)\,\sqrt{ab\delta} + \sqrt{a\delta} \\ & * \sqrt{\left(a\delta + (R-\alpha)\,\sqrt{4ab\delta} + b\,((R-\alpha)^2 + 4LR\beta)\right)}\Big\} \end{aligned}$$

where

$$\delta = 4bK - R^2$$

The equilibrium number of firms in both sectors is again found by rounding down. In the simulation model, the number of firms is an integer, and therefore, firm output and emissions need no longer be identical under the two schemes. Firm output and emission are given by

$$q^p = \frac{\alpha - R}{2a + n^p\beta}$$

$$q^c = \frac{n^c\left(\alpha - R\right) + \sqrt{\left(n^cR - n^c\alpha\right)^2 + 4Ln^cR\left(2a + n^c\beta\right)}}{2n^c\left(2a + n^c\beta\right)}$$

$$E^p = q^p - \frac{R}{2b}$$

$$E^c = q^c - \frac{R}{2b}$$

The equations for n^p, n^c, E^p, E^c are all functions of R. Inserting these equations in the emissions constraint (4.141) gives an equation with only R unknown. This can then be solved and used to solve for the other unknowns.

4.C.2 Imperfect Competition

No Regulation Assuming that all firms are identical, profits are given by:

$$\pi_i = p(Q)q_i - aq_i^2 - b(q_i - E_i)^2 - K$$

where $Q = \sum_{i=1}^{n} q_i$. Using the demand function (4.38), the first order conditions are:

$$\frac{\partial \pi_i}{\partial q_i} = \alpha - \beta q(n+1) - 2aq_i - 2b(q_i - E_i) = 0$$

$$\frac{\partial \pi_i}{\partial E_i} = 2b(q_i - E_i) = 0 \quad \Rightarrow \quad q_i = E_i$$

In the long run all firms in the market should at least cover their costs, i.e., $\pi_i \geq 0$ and entry should not be profitable. These conditions can be given as:

$$\pi_i(n^0) \geq 0, \quad \text{and} \quad \pi_i(n^0 + 1) < 0$$

where n^0 is the equilibrium number of firms in the market without regulation. Denote by $\tilde{n}$ the equilibrium number of firms without taking the integer constraint into account. This is given by:

$$\tilde{n} = \frac{-2\,a\,\sqrt{K} - \sqrt{K}\,\beta + \alpha\,\sqrt{a+\beta}}{\sqrt{K}\,\beta}$$

The equilibrium number of firms in the market, n^0, is then given by the greatest integer less than or equal to $\tilde{n}$. The equilibrium output level per firm is given by:

$$q_i^0 = \frac{\alpha}{2a + (1+n^0)\beta}$$

Permit Trading The profit function for the firm becomes:

$$\pi = p(Q)q - aq^2 - b(q-E)^2 - K - R^p(E - \bar{E})$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = \alpha - \beta q(n+1) - 2aq - 2b(q-E) = 0 \tag{4.143}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) - R^p = 0 \tag{4.144}$$

Since we have assumed that firms are identical, emissions after trading will be $E = L/n$.

Equilibrium output per firm follows from (4.143)

$$q = \frac{2\,b\,L + n\,\alpha}{n\,\left(2\,a + 2\,b + \beta + n\,\beta\right)} \tag{4.145}$$

The equilibrium number of firms can be found by solving for q in the zero profit condition and setting it equal to (4.145)

$$2K = \frac{2bL^2}{\tilde{n}^2} + \frac{\lambda\beta}{\tilde{n}^2\nu^2} + \frac{\mu - \lambda\beta}{\tilde{n}\nu^2} + \frac{\alpha^2\beta(1-\tilde{n}) - \mu}{\nu^2} - \frac{\lambda}{\tilde{n}^2\nu} + \frac{\alpha^2}{\nu} \tag{4.146}$$

where

$$\lambda = 4b^2L^2, \quad \mu = 4bL\alpha\beta, \quad \text{and} \quad \nu = 2a + 2b + \beta + \tilde{n}\beta$$

The equilibrium number of firms is found by solving (4.146) for $\tilde{n}$ and rounding down to the nearest integer.

Credit Trading With credit trading, the profits of a firm become:

$$\pi = p(Q)q - aq^2 - b(q-E)^2 - K - R^cE - \bar{e}q)$$

where $\bar{e} = L/Q$. The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = \alpha - \beta q(n+1) - 2aq - 2b(q-E) + R^c\left(\frac{L}{Q} - q\frac{L}{Q^2}\right) = 0 \qquad (4.147)$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) - R^c = 0 \qquad (4.148)$$

The equilibrium output can be found from (4.147)

$$q = \frac{2bLn\,(2n-1) + n^3\alpha + \phi}{2n^3\nu} \qquad (4.149)$$

where

$$\phi \equiv \sqrt{\left(-2bLn + 4bLn^2 + n^3\alpha\right)^2 - 8bL^2\,(-1+n)\,n^3\,(\nu)}$$

The equilibrium number of firms can be be found by solving for q in the zero profit condition and setting it equal to (4.149)

$$\begin{aligned}4K =& \frac{\alpha^2}{\nu} - \frac{4bL^2}{\tilde{n}^3} + \frac{\alpha\beta(\alpha - \tilde{n}\alpha - 8bL)}{\nu^2} - \frac{4b^2L^2}{\tilde{n}^4\nu} - \frac{8bL^2\beta}{\tilde{n}^2\nu} + \frac{2bL\phi}{\tilde{n}^5\nu} - \frac{2bL\beta\phi}{\tilde{n}^5\nu^2}\\ &+ \frac{2bL\beta(2bL+3\phi)}{\tilde{n}^4\nu^2} + \frac{32b^2L^2\beta - 4bL\alpha\beta - \alpha\beta\phi}{\tilde{n}^2\nu^2} + \frac{4bL\beta(3\alpha - 4bL)}{\tilde{n}\nu^2}\\ &+ \frac{4bL(L\beta + \alpha)}{\tilde{n}\nu} + \frac{\alpha\beta\phi - 20b^2L^2\beta - 4bL\beta\phi}{\tilde{n}^3\nu^2} + \frac{\alpha\phi + 8b^2L^2 + 4bL^2\beta}{\tilde{n}^3\nu}\end{aligned}$$

The equilibrium number of firms is found by solving this for $\tilde{n}$ and rounding down to the nearest integer.

Combined Trading Here we need the following conditions

$$2L = n^c E^c + n^p E^p \tag{4.150}$$

$$R^p = R^c = R$$

For the permit sector we can derive the following equations for output per firm and the number of firms in the permit sector from (4.145), (4.144) and the zero profit condition

$$q^p = \frac{-R + \alpha}{2\,a + \beta + n^p\,\beta}$$

$$\begin{aligned} & 4bK - R^2 + \frac{2b\beta(\tilde{n}^p R^2 + 2R\alpha + \tilde{n}^p \alpha^2)}{\eta^2} + \frac{4bR\alpha}{\eta} \\ = \quad & \frac{2b\beta\left(R^2 + 2\tilde{n}^p R\alpha + \alpha^2\right)}{\eta^2} + \frac{2b(R^2 + \alpha^2)}{\eta} \end{aligned}$$

where

$$\eta \equiv 2a + \beta + \tilde{n}^p \beta$$

This can be solved numerically. The equilibrium number of firms for every emission quota price R is found by rounding the value for $\tilde{n}^p$ down to the nearest integer.

Also under imperfect competition, the relative standard for the credit sector is now given by L/nq. For output per firm in the credit sector, we find from (4.147) and (4.148)

$$q^c = \frac{n^{c2}\,(\alpha - R) + \sigma}{2n^{c2}\rho} \tag{4.151}$$

where

$$\rho \equiv 2a + \beta + n^c\beta, \quad \sigma \equiv \sqrt{n^{c4}(R-\alpha)^2 + 4L\,(-1 + n^c)\,n^{c2}R\,(\rho)}$$

The number of firms in the credit sector can be derived from (4.151) and the zero profit condition

$$\begin{aligned}
& 4bK - R^2 + \frac{b\beta(n^c R^2 + 2R\alpha + n^c\alpha^2)}{\rho^2} + \frac{2bR(\alpha + L\beta)}{\rho} \\
& + \frac{bR(\sigma + 2L\beta) - b\alpha\sigma}{n^{c2}\rho} + \frac{b\beta\sigma(R-\alpha)}{n^{c2}\rho^2} - \frac{2bLR}{n^{c2}} - \frac{2bLR}{n^c} \\
= \quad & \frac{b\beta(R^2 + 2n^c R\alpha + \alpha^2)}{\rho^2} + \frac{b(R^2+\alpha^2)}{\rho} + \frac{4bLR\beta}{n^c\rho} + \frac{b\beta\sigma(R-\alpha)}{n^c\rho^2}
\end{aligned}$$

Using these equations and the first order condition for emissions, we can derive equations for n^p, E^p, n^c, and E^c that are only functions of R. However, because the number of firms in each sector is an integer, and the expressions above give a rational number, we cannot derive an expression for the equilibrium value of R. Instead, the equilibrium value of R was found through iteration, where the starting value of the iteration was R^p for every case and a small amount was added until the equilibrium value was found.

Chapter 5

A Smooth Path or a Bumpy Ride? An Analysis of the Transitory Phase of Environmental Regulation

5.1 Introduction

In modelling environmental regulation, it is usually assumed that firms and the industry as a whole adjust instantaneously to the new regulation and move to the new equilibrium. The transitory phase is not modelled and it is implicitly assumed that the path to the new equilibrium is a smooth one. The fact that this phase is not modelled could be interpreted as implying that this path is not important and that the transitory phase is just that, something that will go away. The new equilibrium will arise and it is this outcome we are interested in.

However, the transitory phase is of importance and needs more attention. If the path to the new equilibrium is rather volatile, firms will incur costs from the uncertainty that surrounds them. Prices observed now need not be a good prediction of prices in the future. Hence, the efficiency of an instrument also depends on how fast and how smooth it gets the industry from no regulation to the new equilibrium with regulation. That is, if the industry reaches the new equilibrium at all. It is possible that the path embarked on with the implementation of regulation is so volatile that the industry never settles down in an equilibrium.

This chapter explicitly models the transitory phase for four instruments, absolute standards, relative standards, credit trading and permit trading, in both a perfectly and an imperfectly competitive industry. For that purpose, a dynamic model is developed in which firms can enter or exit the market, depending on the profitability of the incumbent firms. Two scenarios are analyzed. In the first scenario, the standard that will hold in the equilibrium with regulation is set from the first period. In the second scenario, environmental policy is revised in every period according to the situation in the previous period. Relative standards are defined as allowed emissions per unit of output. Since total output can change in every period, the standard has to be adjusted to realize the emission target. The same holds for credit trading since this form of emissions trading is based on relative standards. With absolute standards, the quantity of allowed emissions per firm will have to be adjusted with entry or exit. For emissions trading, no such adjustment is needed, since there exists a ceiling on total emissions which is realized in every period.

This chapter builds on work by Dijkstra (1999) and chapter 4. Dijkstra (1999) analyzes the effect of different instruments on a perfectly competitive industry, given that the government wants to achieve a certain abatement level. He shows that different instruments have different impacts on the industry, with relative standards leading to the highest output level and permit trading with grandfathering leading to the highest profits. These results clearly have implications for the political acceptability of the different instruments. Chapter 4 gave a model of permit and credit trading, analyzing both perfect and imperfect competition (see also Fischer 2001 and Gielen et al. 2002). Chapter 4 showed that the two types of emissions trading have different impacts on the industry. The specific model used in chapter 4 is also used in this chapter.

This chapter is organized as follows. In the next section, the model is developed. Sections 5.3 and 5.4) present the regulation scenarios and simulation results for perfect, respectively imperfect competition. Several cases are given to illustrate the effect of regulation on the industry. In Section 5.5 some general conclusions are given.

5.2 The Model

Consider an industry, consisting of n firms that produce a homogeneous good. Production per firm is given by q and the price of the good is p. In producing the good, firms emit a pollutant E, which the government wants to regulate. The overall goal of the government is to limit total emissions to the level L.

Firm costs are given by

$$C(q, E) = aq^2 + b(q - E)^2 + K \tag{5.1}$$

Here, a and b are parameters and K gives fixed costs, with $a, b, K > 0$. For this cost function, it holds that $C_q > 0$, $C_{qq} > 0$, $C_E < 0$, $C_{EE} > 0$, $C_{qE} = C_{Eq} < 0$.

The inverse demand function is linear and is given by

$$p = \alpha - \beta nq \tag{5.2}$$

with $\alpha, \beta > 0$.

In the following, I will analyze the effect of four forms of environmental regulation on the industry; permit trading, credit trading, relative standards and absolute standards. Under permit trading, the government divides the total emission ceiling in permits and distributes these over the polluters, either by grandfathering or auctioning, after which the polluters can trade the permits. With credit trading, the government sets a relative standard that limits emissions per unit of output. Firms that can stay below this relative standard can sell credits. Absolute standards set a ceiling on emissions per firm. I will first discuss the case when there is perfect competition, and then when there is imperfect competition in the industry. In both cases, the necessary models are developed after which they are used to generate simulations that show the functioning of the instruments under different circumstances.

We analyze two forms of government behavior; myopic behavior and perfect foresight. With perfect foresight, the government knows the optimal long-run standard under credit trading and relative and absolute standards. The government then implements this long-run standard from the start. With permit trading, the government does not set a standard, so here the type of foresight of the government does not matter. With myopic behavior, the government sets its policy in each period based on information from the previous period. Hence, with absolute standards, the government sets the limit on emissions per firm at time t, $\bar{E}_t$, by dividing the limit on total emissions by the number of firms in the previous period:

$$\bar{E}_t = L/n_{t-1} \tag{5.3}$$

With permit trading, there are two possibilities. One possibility is that the government hands out permits every period to firms that produced output in the previous period, so that $\bar{E}_t$ is given by (5.3). This implies that new entrants will have to buy their way into the market. Firms that exit sell their permits and cease to exist, where exiting firms are defined as those that set output equal to zero. Alternatively, the government could auction the permits at the beginning of every new period. Both ways of distributing will give the same outcome in the model. With perfect foresight, the government sets the long run equilibrium values of the different instruments from the start of the regulation program. Combined trading does not alter the way the government sets its policy.

With relative standards and credit trading, the relative standard is given by the emission limit divided by total output in the previous period:

$$\bar{e}_t = L/(n_{t-1}q_{t-1}) \tag{5.4}$$

Although an equilibrium can be derived, especially under perfect competition (see chapter 4), exit and entry of firms is used to create dynamics in the system. Exit and entry are modelled similarly, but slightly differently under perfect and imperfect competition. In both cases, entry (exit) occurs in period t when there are positive (negative) profits in period $t-1$. Then for perfect competition, let the number of firms in the sector at period t be

$$n_t = n_{t-1} + \gamma \left(\frac{Q_{t-1}}{q_{t-1}^{min}} - n_{t-1} \right) \tag{5.5}$$

Here $\gamma > 0$ gives the rate of adjustment and q^{min} is the output level at which a firm earns no profit. That is, q^{min} is the level of output where marginal costs are equal to average costs, where costs include both operating costs and all costs of regulation. It should be noted that the q^{min} calculated in this way does not necessarily give the long-run output level. It gives the lowest cost output level taking present regulation as given. Specifically, in calculating q^{min}, the absolute or relative standards are taken as given or the permit price (both under permit trading and combined trading) is taken as given. If present regulation is not at its long-run equilibrium level, then neither will q^{min} be.

Using (5.5) implies that entry will happen when profits are positive, while there will be exit when profits in the industry are negative. To see this, note that when firms make a profit, their output is higher than q^{min}. Equation (5.5) says that firms will enter (exit) when output per firm is higher (lower) than q^{min}. Using (5.5) has the advantage that it can be readily seen how fast firms adjust. So when $\gamma = 1$, firms adjust fully in the sense that if policy does not change, entry or exit will be such that, in the next period, profits are zero in the industry. Setting $0 < \gamma < 1$ then gives slower than full adjustment, while $\gamma > 1$ gives more than full adjustment (or over-adjustment).

The number of firms in the industry is an integer. However, (5.5) does not necessarily give an integer. To deal with this problem, the number of firms found through the use of (5.5) is rounded down to the nearest integer.

In the dynamic model of oligopoly, presented in section 5.4, firms take the output of their competitors as given. More specifically, they assume that the output levels of their rivals will be the same as they were in the previous period. Furthermore, the government sets the relative and absolute standards in the myopic manner as described above under perfect competition. This will be compared with the case were the long-run equilibrium value of the standards is set from the beginning. Under perfect competition the number of firms was assumed to change as a function of profit in the previous period. A similar method was employed under imperfect competition. We assume that firms determine how many firms there can be in the current period. Then entry or exit occurs in the next period up to the level that could have been sustained in the previous period. This is exactly the same as what happens under perfect competition with $\gamma = 1$.

5.3 Perfect Competition

In this section, the transition from a state without regulation of emissions to a new state with restrictions on emissions is simulated in the case of perfect competition. In subsection 5.3.1 the discrete time model is given for the various types of regulation. In subsection 5.3.2, the simulation results of the transition phase are presented and discussed.

5.3.1 Regulation scenarios

No Regulation. The situation without regulation is the starting point of the analysis and gives a benchmark for the changes caused by regulation. We will assume that the industry is in long-run equilibrium before regulation is introduced. In this case, profits for a firm are, from (5.1):

$$\pi = pq - C(q, E) = pq - aq^2 - b(q - E)^2 - K$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q - E) = 0 \tag{5.6}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) = 0 \quad \Rightarrow \quad q = E \tag{5.7}$$

Besides these conditions, in the long run it must hold that $pq = C(q, E)$, i.e., there should be no profits:

$$2aq + 2b(q-E) = \frac{aq^2 + b(q-E)^2 + K}{q}$$

Using (5.7) we find

$$q = \sqrt{\frac{K}{a}}$$

To find the market price of the good, insert this into (5.6) to find:

$$p = 2a\sqrt{\frac{K}{a}}$$

The total number of firms is found by inserting the market price in (5.2) and solving for n. This gives

$$n = \frac{\alpha\sqrt{\frac{a}{K}} - 2a}{\beta}$$

The three equations for q, p and n fully determine the equilibrium in the no regulation case.

Permit Trading. With permit trading, the government distributes the total limit on emissions as permits over the firms. Let $\bar{E}_i \geq 0$ be the amount of permits received by firm i. The maximization problem for the firm (suppressing the i's) is, from (5.1):

$$\begin{aligned} \max_{q,E} \quad \pi &= pq - C(q,E) - R^p(E - \bar{E}) \\ &= pq - aq^2 - b(q-E)^2 - K - R^p(E - \bar{E}) \end{aligned}$$

where R^p is the permit price. The first order conditions are given by

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q-E) = 0 \tag{5.8}$$

$$\frac{\partial \pi}{\partial E} = 2b(q-E) - R^p = 0 \tag{5.9}$$

In this case, with identical firms, emissions trading will equalize emissions between firms in every period, i.e., $E = L/n$. Using this, and inserting for p from the inverse demand function given in (5.2), we find

$$q = \frac{2b\frac{L}{n} + \alpha}{2a + 2b + n\beta} \tag{5.10}$$

In the long run, firms regulated through permit trading will have to cover both their operating costs $C(q,E) = aq^2 + b(q-E)^2 + K$ and the opportunity costs of emissions R^pE. That is, in the long run

$$\pi = pq - aq^2 - b(q-E)^2 - K - R^pE \geq 0 \tag{5.11}$$

The reason for this is that if the firm does not cover the opportunity costs on emissions, it would be better off closing down and selling the permits.

In the analysis, we use the minimum average costs level of output. This output level is given as the q where $\pi = 0$ in (5.11). With permit trading, q^{min} is found by setting long-run average costs, including the opportunity costs of emissions, equal to marginal costs:

$$\frac{aq^2 + b(q-E)^2 + K + R^pE}{q} = 2aq + 2b(q-E) \tag{5.12}$$

Using (5.9) to eliminate E and solving for q gives

$$q^{min} = \frac{\sqrt{4bK - R^2}}{\sqrt{4ab}}$$

During every period then the number of firms is fixed. Using this, q and $Q = nq$ can be found. From this, the price of the good can be derived using (5.2).

Credit Trading and Relative Standards With relative standards, the government sets a limit $\bar{e}$ on the emissions per unit of output. The firm is then allowed to emit $\bar{e}q$ in total. With credit trading, the firm is allowed to sell credits if it can stay below the total allowed emission level for the firm. Since we are dealing with identical firms in the model, no trade will take place. Therefore, the analysis of credit trading and relative standards becomes identical, except for the fact that under credit trading there is a credit price R^c, while with relative standards, there is a shadow price. In the following, I will concentrate on credit trading.

Under regulation with credit trading, the firm will maximize, from (5.1):

$$\begin{aligned}\pi &= pq - aq^2 - C(q, E) - R^c(E - \bar{e}q) \\ &= pq - aq^2 - b(q - E)^2 - K - R^c(E - \bar{e}q)\end{aligned}$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q} = p - 2aq - 2b(q - E) + R^c\bar{e} = 0 \tag{5.13}$$

$$\frac{\partial \pi}{\partial E} = 2b(q - E) - R^c = 0 \tag{5.14}$$

With identical firms there is no scope for trading, and all firms will emit up to the allowed amount, i.e., $E = \bar{e}q$. Using this, and inserting for p from (5.2) we find

$$q = \frac{\alpha}{2a + 2b(\bar{e} - 1)^2 + n\beta} \tag{5.15}$$

In this case, there are two variables that need to be determined, n and $\bar{e}$. As with permit trading, n is determined through (5.5) with q^{min} for relative standards now given by

$$q^{min} = \frac{\sqrt{K}}{\sqrt{a + b(\bar{e} - 1)^2}}$$

and q^{min} for credit trading given by

$$q^{min} = \frac{\sqrt{4bK - R^2}}{\sqrt{4ab}} \tag{5.16}$$

The two equations for q^{min} are found by setting long-run average costs equal to marginal costs and then using (5.14) and (5.4) to eliminate E and R or $\bar{e}$.

Absolute Standards With absolute standards, the government sets a limit $\bar{E}$ on emissions per firm. Since firms are identical in this model, the analysis of absolute standards is rather similar to the analysis of permit trading above. However, there is one difference in that the firm does not have to cover opportunity costs of emissions. Hence, with absolute standards, it must hold that

$$\pi = pq - aq^2 - b(q - \bar{E})^2 - K \geq 0 \tag{5.17}$$

It is clear that this is different from the long-run profit function for permit trading given by (5.11). Otherwise, the first order conditions derived for permit trading also hold under absolute standards, with the difference that R^p is replaced by a shadow price λ.

This also implies that q^{min} for absolute standards is different from the one under permit trading. In this case, q^{min} found by setting long-run average costs equal to marginal costs

$$q^{min} = \frac{\sqrt{K + b\bar{E}^2}}{\sqrt{a+b}}$$

Combined Trading The model can also be used to analyze the effects of combining permit and credit trading. With perfect competition, the only interesting case is the one where two sectors operating on different product markets are connected through emissions trading. If two sectors, from different countries for example, operating on the same product market would be connected through emissions trading, the sector regulated through permit trading would vanish because of its higher marginal production costs.

In the following, we assume that the two sectors are identical in all aspects, except that they operate on two different goods market, which have the same demand function, and that one sector is regulated through permit trading, while the other is regulated through credit trading. In the case of combined trading, an additional condition is needed, given by

$$n^c E^c - n^c q^c \bar{e}^c = n^p \bar{E}^p - n^p E^p$$

where the superscripts c and p denote the credit and permit sectors respectively. This condition merely says that total emissions should be equal to total allowable emissions. Using this condition, together with the first order conditions for profit maximization for both sectors given in (5.8), (5.9), (5.13) and (5.14) and inverse demand function (5.2), the price of emission quotas can be determined as

$$\begin{aligned} R = \quad & \Big\{ -2b \left(4a^2 n^p \bar{E} + n^c n^p \beta \big[(\bar{e} - 2)\, \alpha + n^p \bar{E} \beta \right) \\ & \quad + 2a \left(n^p \left(n^p \bar{E} \beta - \alpha \right) + n^c \left((\bar{e} - 1)\, \alpha + n^p \bar{E} \beta \right) \right) \big] \Big\} \\ & \Big/ \Big\{ 4a^2 \left(n^c + n^p \right) + n^c n^p \beta \left(2b \left(2 - 2\bar{e} + \bar{e}^2 \right) + \left(n^c + n^p \right) \beta \right) \\ & \quad + 2a \left(2b \left(n^p + n^c \left(\bar{e} - 1 \right)^2 \right) + \left(n^c + n^p \right)^2 \beta \right) \Big\} \end{aligned}$$

The quota price can then be used directly in the first order conditions to calculate q^c and q^p and the other variables.

The output of a firm in the permit sector is given by

$$q^p = \frac{\alpha - R}{2a + \beta n}$$

The output of a firm in the credit sector is

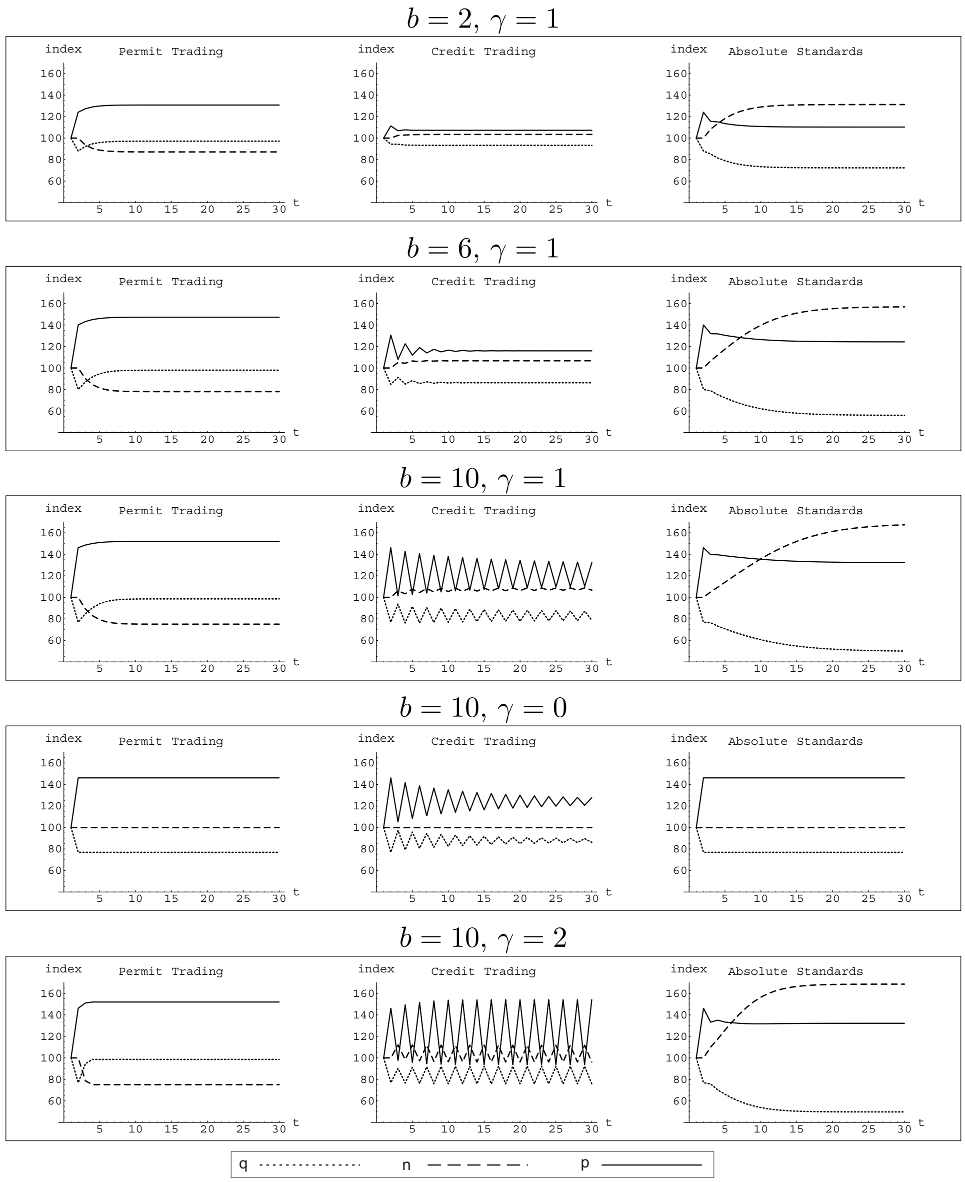
$$q^c = \frac{\alpha - R(1 - \bar{e})}{2a + \beta n}$$

Emissions in both cases are given by

$$E = q - \frac{R}{2b}$$

Figure 5.1: Perfect Competition, Myopic Government, Inelastic Demand

$$a = 1,\ K = 1,\ \alpha = 6,\ \beta = 0.04$$



Also q^{min} changes for both cases. More precisely, q^{min} becomes identical for the two cases (see chapter 4)

$$q^{min} = q^{min} = \frac{\sqrt{4bK - R^2}}{\sqrt{4ab}}$$

The equations for emission quota price, output, emissions and zero profit output together with demand function (5.2), fully characterize the equilibrium in the combined system.

5.3.2 Simulation results

The results of the simulation[1] for perfect competition are reported in Figures 5.1 through 5.10. We will first discuss the case where the government behaves myopically. The simulation results for this are given in Figures 5.1 through 5.4. Figure 5.1 gives some cases with inelastic demand. The price elasticity of demand in the starting position without regulation is -0.5 in this case. Figures 5.2, 5.3 and 5.4 give cases with elastic demand. The price elasticity of demand in the starting position here is -1.25 for Figure 5.2 and -2 for Figures 5.3 and 5.4. Figures 5.5 through 5.7 give some of the same cases, but for combined trading.

In all cases, the initial condition is the same, with $q^n = 1$, $E^n = 1$, $p^n = 2$ and $n^n = 100$, where the superscript n denotes the no regulation case. Total emissions without regulation are then 100 and in all cases, except the last case in Figure 5.3, emissions are reduced by 30% giving a limit on total emissions of 70. Environmental policy is introduced in period two. In all figures, the dotted line gives output per firm, the drawn line gives price of output and the dashed line gives the number of firms. The values in the figures give the index relative to the no-regulation case.

In the following, we will concentrate on the dynamic effects of regulation and pay little attention to the comparative statics effects. For the latter, at least for permit and credit trading, the reader is referred to chapter 4.

[1]The simulation algorithm was programmed in Fortran and is available from the author upon request

Figure 5.2: Perfect Competition, Myopic Government, Elastic Demand 1

$$a = 1,\ K = 1,\ \alpha = 3.6,\ \beta = 0.016$$

$$b = 2,\ \gamma = 1$$

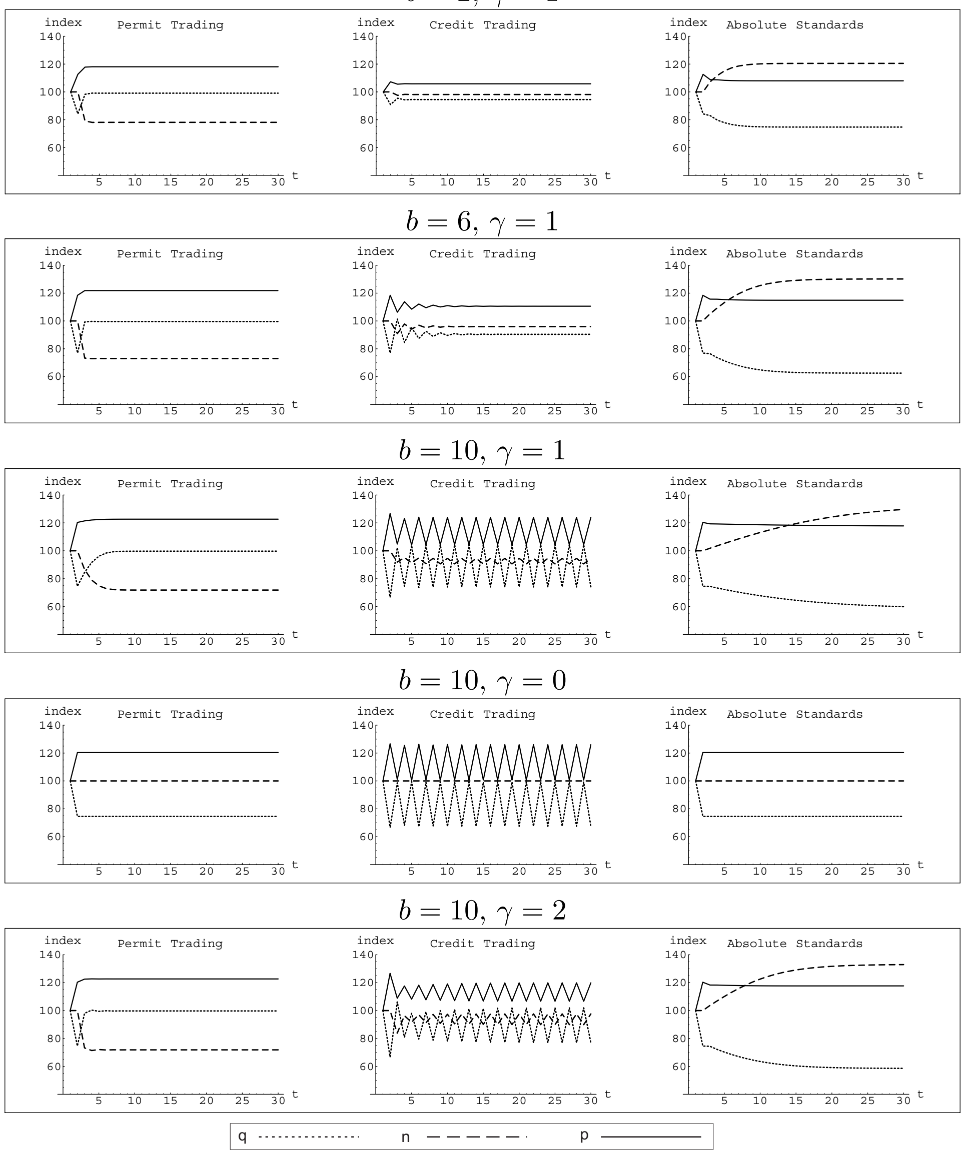


Figure 5.3: Perfect Competition, Myopic Government, Elastic Demand 2a

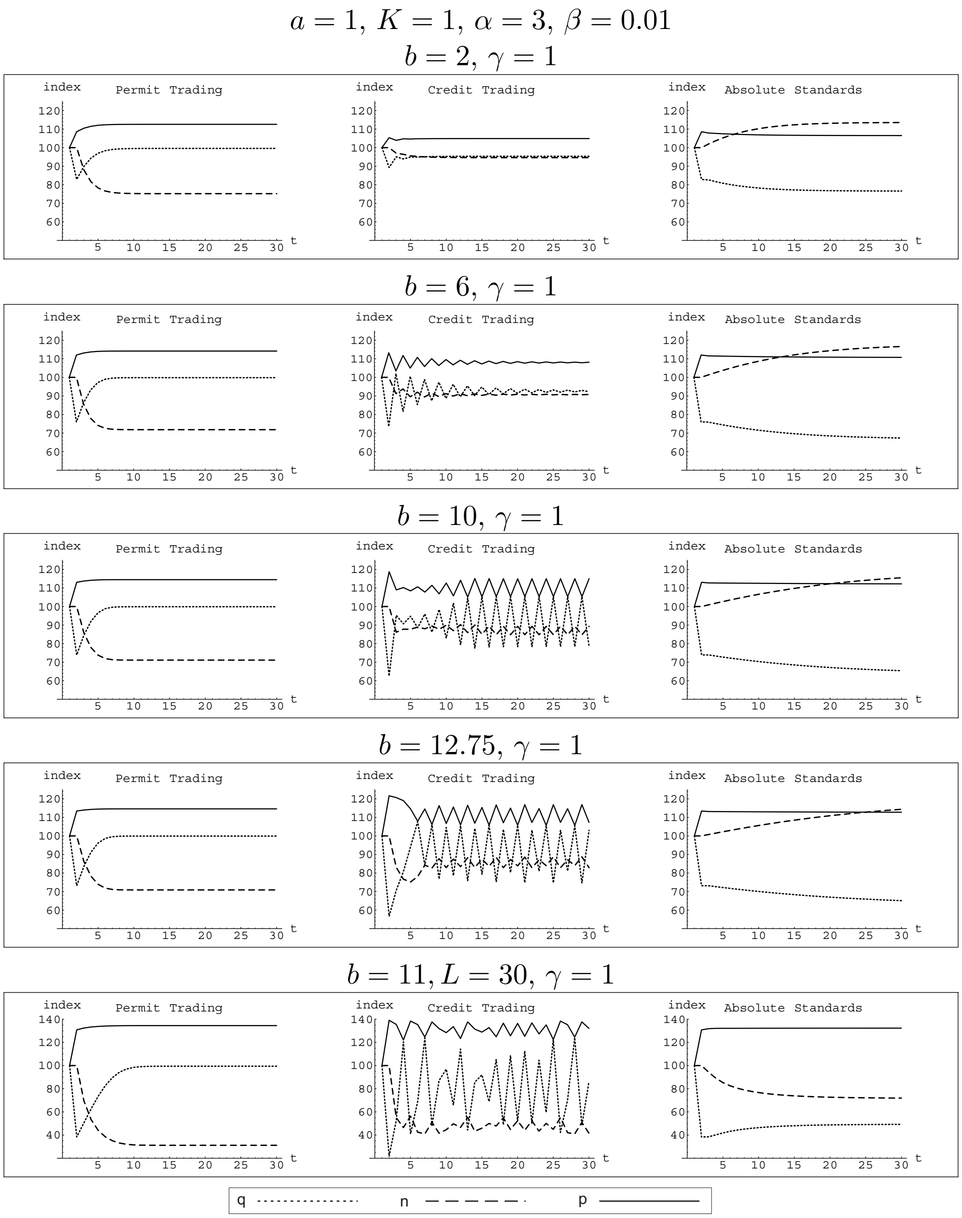
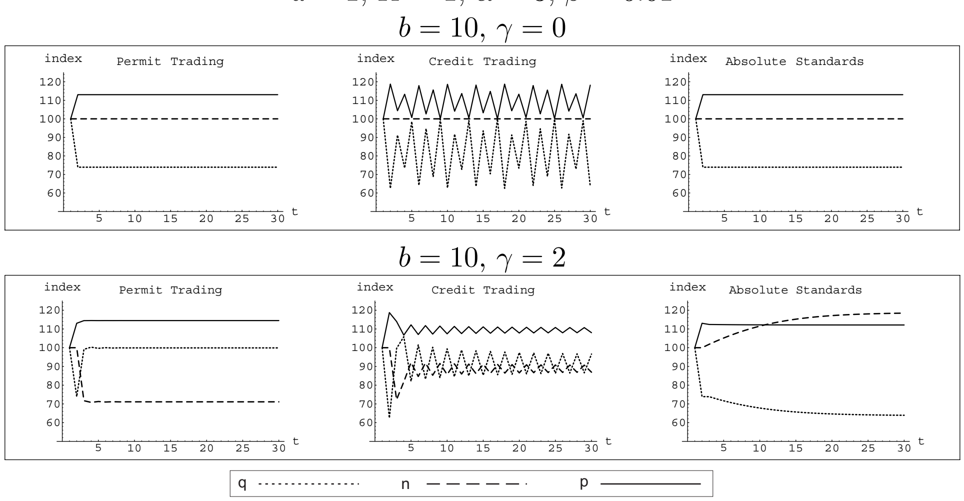


Figure 5.4: Perfect Competition, Myopic Government, Elastic Demand 2b

$a = 1$, $K = 1$, $\alpha = 3$, $\beta = 0.01$



One important aspect however is entry and exit of firms. Environmental regulation diminishes the efficient scale of operation of the firm. Whether environmental regulation then leads to entry or exit depends on the elasticity of demand. If demand is rather inelastic, total output will not change by much as a result of environmental regulation and firms will enter. When demand is elastic, total output will decrease by a large amount, and firms will exit.

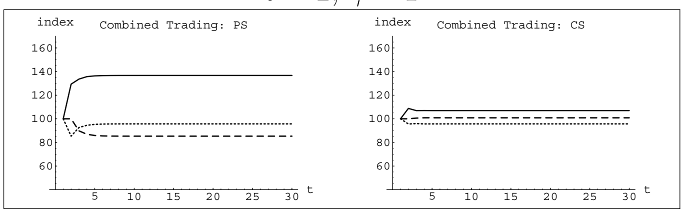
A number of interesting features are shown in the figures. First of all, the transition from no regulation to regulation is often not very smooth, but may be rather volatile, especially with credit trading. Secondly, in most cases, credit trading (or relative standards) leads to less change in the long-run equilibrium than permit trading and absolute standards do. This was already shown in chapter 4. Thirdly, immediately setting the standard (relative or absolute) at its long-run equilibrium level may lead to a longer transition period than myopic behavior by the government.

We start with the volatility in the market caused by regulation. As the figures show, there are basically two types of volatility. The first one is very

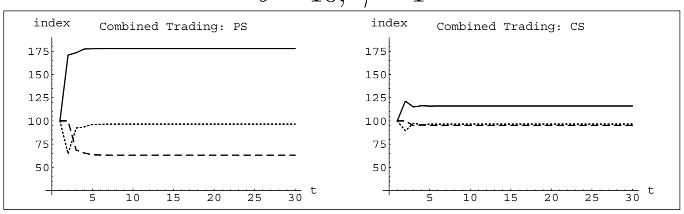
Figure 5.5: Perfect Competition, Myopic Government, Combined Trading, Inelastic Demand

$$a = 1,\ K = 1,\ \alpha = 6,\ \beta = 0.04$$

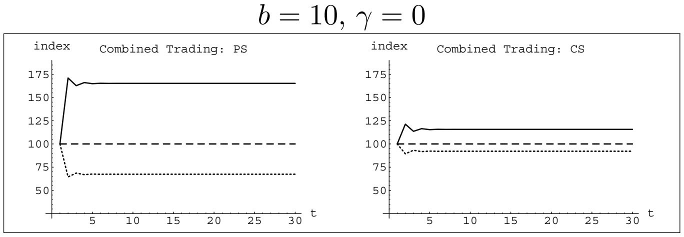
$$b = 2,\ \gamma = 1$$



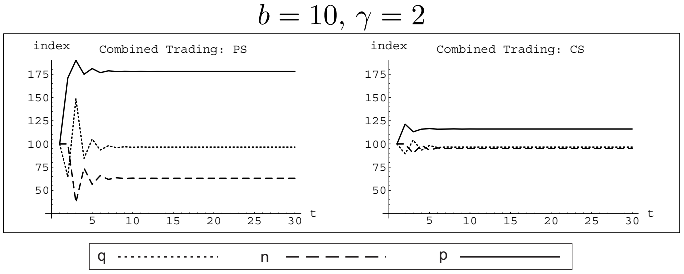
$$b = 10,\ \gamma = 1$$



$$b = 10,\ \gamma = 0$$



$$b = 10,\ \gamma = 2$$

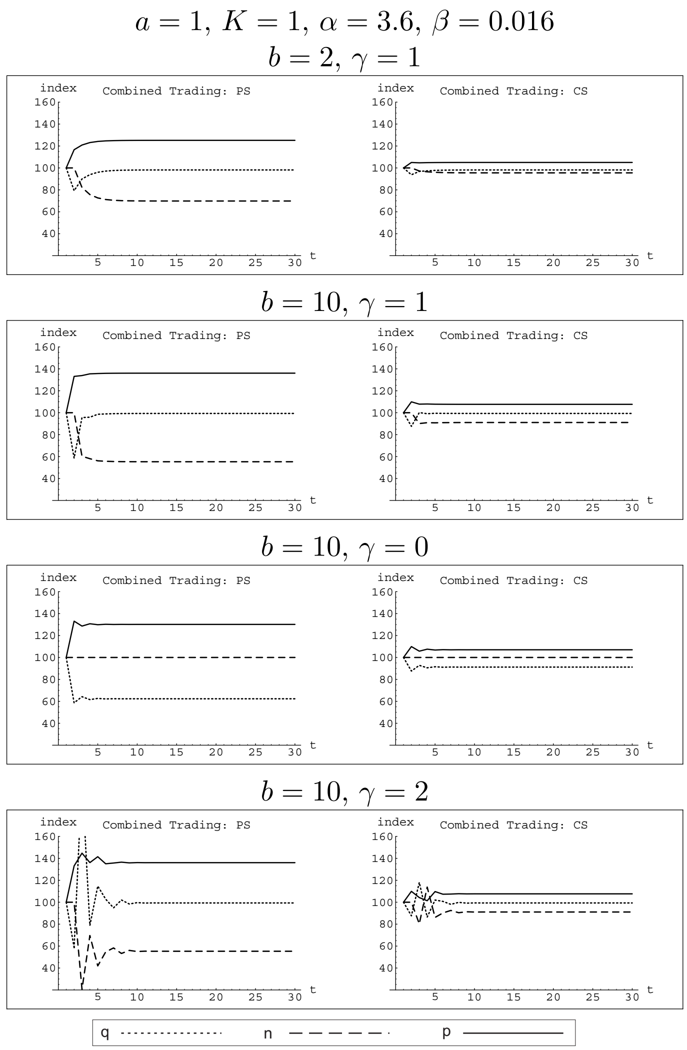


short lived: the introduction of regulation can lead to a strong reaction in the first periods, whereafter the system more or less smoothly moves to the new equilibrium. This is clear in many of the cases, also when the optimal long-run standards are set from the first period onward.

The second type of volatility is of a more persistent nature, though only credit trading (relative standards) is prone to this type of volatility. Whether the system becomes volatile depends on several factors, such as the elasticity of demand, marginal costs of abatement, the rate of adjustment by firms (given by γ), and government policy. As is clear from a comparison of the figures, there is more volatility with credit trading when demand is elastic and when marginal abatement costs are high. The clearest case is given in Figure 5.3. Here permit trading and absolute standards give a more or less smooth transition path after the initial shock. However, with credit trading, the system becomes more volatile the higher marginal abatement costs become. For $b = 2, \gamma = 1$, credit trading shows a rather smooth path with little divergence from the no regulation case. However, when b becomes larger, the system shows two-period bifurcation ($b = 10, \gamma = 1$) and four-period bifurcation ($b = 12.75, \gamma = 1$). Putting more strain on the system by setting a lower total ceiling makes the system become chaotic ($b = 11, L = 30, \gamma = 1$). Hence, in these cases, the system never reaches an equilibrium. Unfortunately, the model could not be solved for very high elasticity of demand and high marginal abatement costs. However, the higher marginal abatement costs, the more volatile the system also becomes here.

Chaos can arise when there is a non-linear relationship between a variable in a certain period and the same variable in the previous period (see Baumol and Benhabib 1989 and Shone 2002, Ch.7). In our model, there are two relationships that make a connection between the current and the previous value of a variable: the entry/exit condition given in (5.5) and government policy as given by how the standards are set (equations (5.3) and (5.4)). A glance at (5.5) shows that the entry/exit rule gives a linear relationship between the current and the previous number of firms, so that this cannot be the cause of chaos in the model. For government policy, the relationship is different between credit trading (and relative standards) on the one hand

Figure 5.6: Perfect Competition, Myopic Government, Combined Trading, Elastic Demand 1



and absolute standards and permit trading on the other hand. For credit trading with myopic standard setting we find from (5.15) and (5.4)

$$\bar{e}_t = \frac{\beta}{\alpha} L + \frac{2L\left(a + b\left(\bar{e}_{t-1} - 1\right)^2\right)}{\alpha n_{t-1}} \tag{5.18}$$

while for permit trading (if they are grandfathered) and absolute standards we find from (5.10) and (5.3)

$$\bar{E}_t = \frac{L}{n_{t-1}\left(1 + \gamma\left(\frac{q_{t-1}}{q_{t-1}^{min}} - 1\right)\right)} \tag{5.19}$$

Equation (5.18) shows that under myopic standard setting there is a nonlinear relationship between the current and previous relative standard, while (5.19) shows that there is a linear relationship for absolute standards and permit trading. Hence, only with credit trading and myopic setting of the relative standard the system can become chaotic. Whether there will be chaos under credit trading (and relative standards) depends on the values of the parameters, which is also clear from the figures.

The more elastic demand is, the more output will decrease as a result of the introduction of a given level of environmental regulation. With relative standards, this can lead to volatility as was mentioned above. Since the government is myopic, it sets the initial relative standard too strict. Firms react by reducing output by more than would be necessary to meet the overall emission limit. Then, in the next period, the government sets a too lax standard since it sets the standard based on output in the first period after regulation, leading to too high output. The higher the elasticity of demand, the larger the swings in output will be. But then, the government will also set a standard that is further from the correct standard in the initial periods. These effects are magnified with higher marginal abatement costs, since the higher marginal abatement costs are, the larger the reduction in output as a result of environmental regulation. As the figures show, these effects can reinforce each other such that the volatility becomes permanent, and even leads to chaos. It has to be noted though, that chaos is only found at rather extreme values of some of the parameters. Hence, in Figure 2, chaos is found with price elasticity of demand equal to -2 at the starting point and 70% emission reduction.

Entry and exit of firms leads to a movement in the opposite direction from the one following from the shifts in environmental regulation with a myopic regulator. With inelastic demand, higher speed γ of adjustment by firms then leads to higher volatility under credit trading, while with elastic demand, it dampens the volatility caused by shifts in the relative standard. For inelastic demand, we give cases with $\gamma = 0$ (no entry or exit) and $\gamma = 2$ in the last two boxes of Figure 5.1. With $\gamma = 0$, volatility gradually decreases. However, with $\gamma = 2$ there is high volatility under relative standards. This is a result of the high levels of entry and exit by firms. Figures 5.2 and 5.4 show that under credit trading and elastic demand volatility is high when there is no entry and exit ($\gamma = 0$). The higher the speed of entry, the lower the volatility subsequently becomes. To see why this is, start at period two where environmental policy is introduced. The government sets a relative standard based on the output level without environmental regulation. One of the results is that output decreases, and hence, the standard was set too tight. At the same time, profits are negative. Then in period three the government will calculate the relative standard anew, but will now set it too lax since output was very low in the first period with regulation. This will lead to a higher output level in period three. Without exit or entry, this would lead to a higher than optimal total output level. However, because profits were negative in period two, firms will exit in period three and hence total output will not increase by as much as it would have done if the number of firms was fixed. Hence, the exit of firms dampens the volatility in the system.

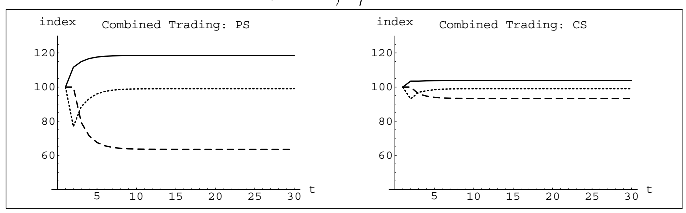
Combining the permit and credit trading in general gives a more smooth transition. A higher speed of entry and exit under combined trading always leads to more volatility as the last boxes in Figures 4 through 6 show.

We now turn to the case where the government sets the long-run equilibrium standards from the start. The results are given in Figures 5.8 through 5.10. For permit trading, the case where policy is set optimally from the

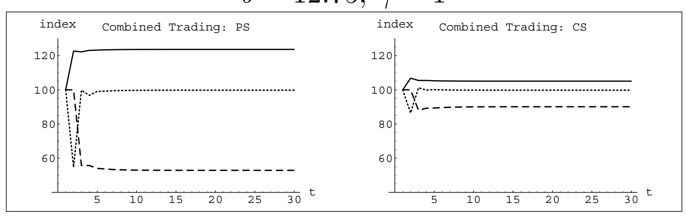
Figure 5.7: Perfect Competition, Myopic Government, Combined Trading, Elastic Demand 2

$a = 1,\ K = 1,\ \alpha = 3,\ \beta = 0.01$

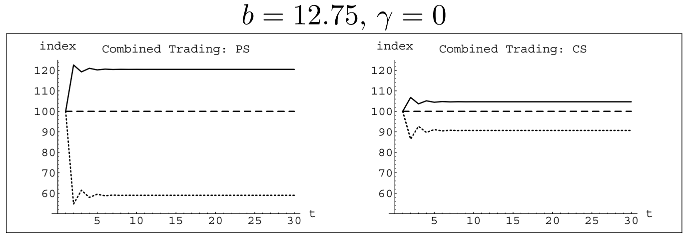
$b = 2,\ \gamma = 1$



$b = 12.75,\ \gamma = 1$



$b = 12.75,\ \gamma = 0$



$b = 12.75,\ \gamma = 2$

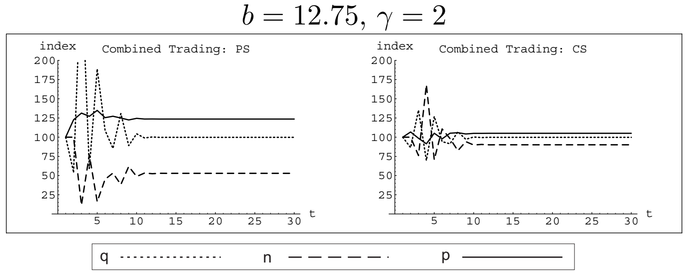
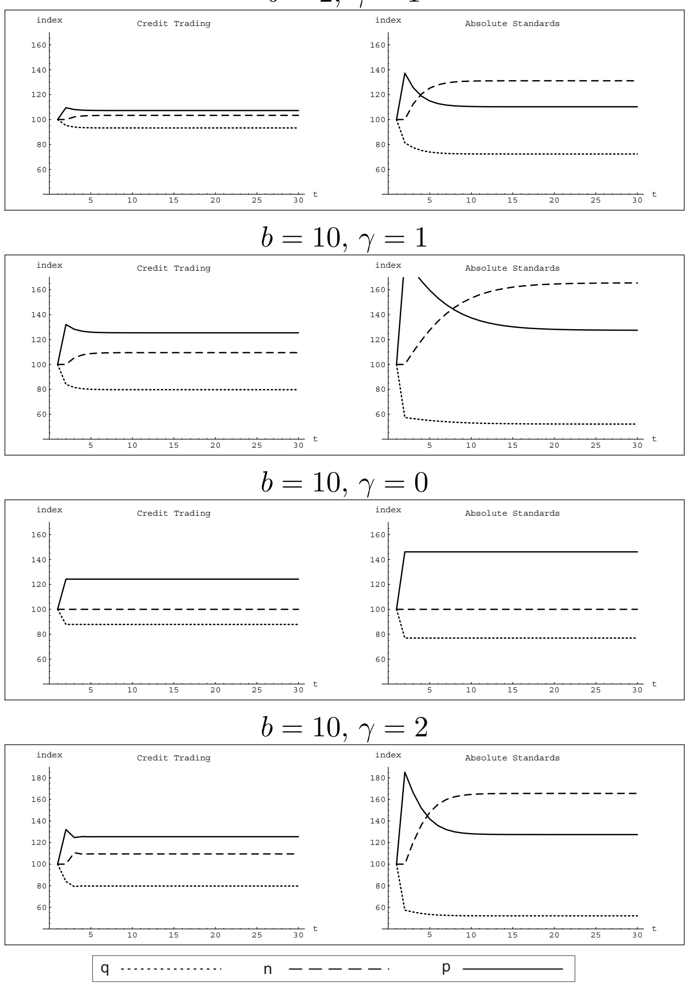


Figure 5.8: Perfect Competition, Constant Standards, Inelastic Demand

$a = 1,\ K = 1,\ \alpha = 6,\ \beta = 0.04$

$b = 2,\ \gamma = 1$



start is identical to the myopic case, therefore, in Figures 5.8 through 5.10 we only give the trajectories for credit trading and absolute standards. The result is that setting a constant standard will give a smooth transition to the new equilibrium, but may lead to a longer transition period than setting a new standard in every period. Again, the result is dependent on the elasticity of demand. Comparing Figure 5.1 and Figure 5.8, it is clear that setting a fixed standard gets the system quicker to the new equilibrium. However, as demand becomes more elastic, the difference becomes smaller. In the first case given in Figures 5.2 and 5.9, with $b = 2, \gamma = 1$, it takes 22 periods for the industry under credit trading to reach equilibrium with both myopic and constant standards. For absolute standards, it takes 54 periods with myopic standards and 46 with fixed standards in the same case. With $b = 10, \gamma = 1$ credit trading does not lead to a stable equilibrium, so nothing can be said about the time it takes to reach the equilibrium. For absolute standards however, it takes 136 periods to reach a stable equilibrium with myopic standards, and 133 periods with constant standards. Hence, in this case, myopic and constant standards lead to virtually the same length of approach path to the new stable equilibrium, if such an equilibrium exists. In the second case with elastic demand, given in Figures 5.3 and 5.10, it takes longer to reach the new stable equilibrium with constant standards than with myopic standards. For example, with $b = 2, \gamma = 1$ it takes 30 periods for credit trading to reach the new equilibrium with myopic standards, while it takes 36 periods with constant standards. For absolute standards, it takes 69 periods with myopic standards and 71 with constant standards. In the case with $b = 12.75, \gamma = 1$, nothing can be said for credit trading because it does not lead to a a stable equilibrium with myopic standards. However, for absolute standards it takes 210 periods to reach the equilibrium with myopic standards and 236 periods with constant standards.

With constant standards, a high speed of entry and exit only leads to more volatility under inelastic demand. The reason for this is that with inelastic demand, total output at first decreases by too much when the optimal standard is set from the start, while with elastic demand, the market adjusts more gradually. With inelastic demand then, the initial spike is sustained and sometimes amplified by entry and exit.

Unfortunately, the model could not be solved for combined trading and constant standards. Therefore, no results for combined trading with constant standards are reported.

5.4 Imperfect competition

In this section, we give the case with oligopoly. In subsection 5.4.1 the discrete time model is given for the various types of regulation. In subsection 5.4.2, the simulation results of the transition phase are presented and discussed.

5.4.1 Regulation scenarios

No Regulation The no-regulation case is used as a starting point for the analysis and as a benchmark to measure changes against. We are therefore only interested in the long-run equilibrium, so no dynamics are incorporated in this stage. Assuming that all firms are identical and keeping the cost function (5.1), profits are given by

$$\pi_i = p(Q)q_i - aq_i^2 - b(q_i - E_i)^2 - K$$

where $Q = \sum_{i=1}^{n} q_i$. Using the demand function (5.2), the first order conditions are

$$\frac{\partial \pi_i}{\partial q_i} = \alpha - \beta Q - \beta q_i - 2aq_i - 2b(q_i - E_i) = 0$$

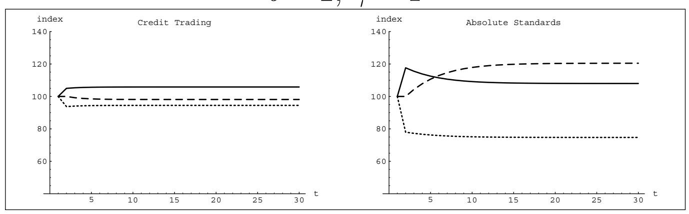
$$\frac{\partial \pi_i}{\partial E_i} = 2b(q_i - E_i) = 0 \quad \Rightarrow \quad q_i = E_i$$

With imperfect competition, firms can earn a profit, even in the long run. However, the number of firms need not be constant over time. The long-run equilibrium conditions with imperfect competition are that all firms in the market should at least cover their costs, i.e., $\Pi_i \geq 0$ and that entry should

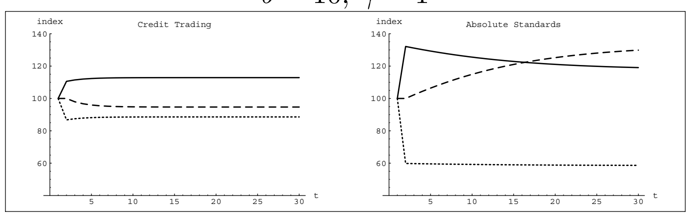
Figure 5.9: Perfect Competition, Constant Standards, Elastic Demand 1

$a = 1,\ K = 1,\ \alpha = 3.6,\ \beta = 0.016$

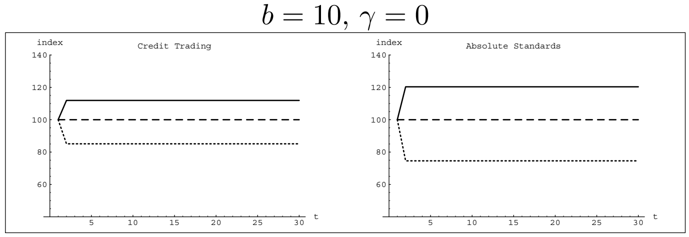
$b = 2,\ \gamma = 1$



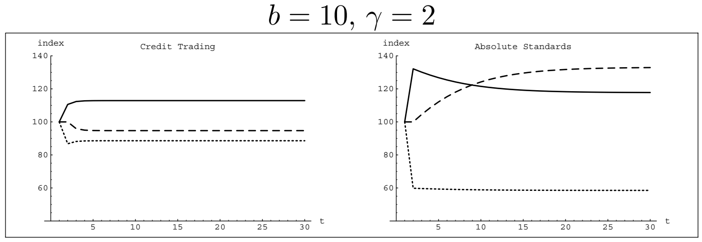
$b = 10,\ \gamma = 1$



$b = 10,\ \gamma = 0$



$b = 10,\ \gamma = 2$



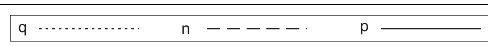
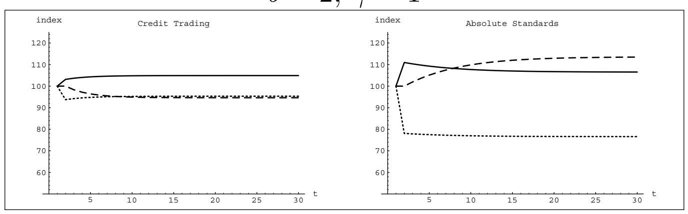


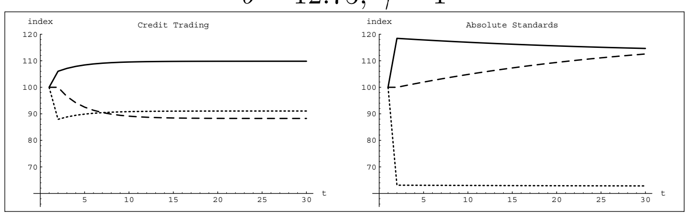
Figure 5.10: Perfect Competition, Constant Standards, Elastic Demand 2

$a = 1$, $K = 1$, $\alpha = 3$, $\beta = 0.01$

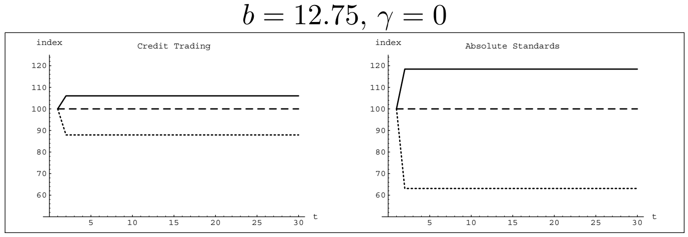
$b = 2$, $\gamma = 1$



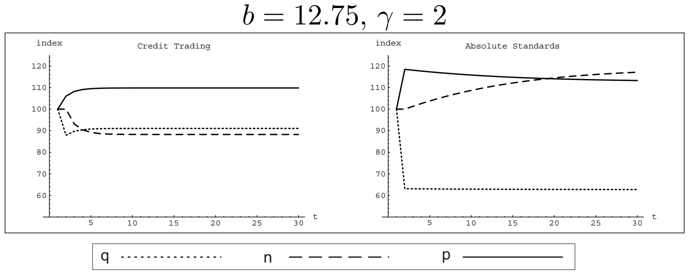
$b = 12.75$, $\gamma = 1$



$b = 12.75$, $\gamma = 0$



$b = 12.75$, $\gamma = 2$



not be profitable. Thus:

$$\pi_i(n^*) \geq 0 \quad \text{and} \quad \pi_i(n^*+1) < 0$$

where n^* is the equilibrium number of firms in the market. The equilibrium output level per firm is then given by

$$q_i = \frac{\alpha}{2a + (1+n^*)\beta}$$

Permit Trading With permit trading, the government puts a limit L on total emissions, giving an initial distribution of permits per firm of $\bar{E} = L/n$. The profit function for the firm then becomes:

$$\pi = p(Q)q_i - aq_i^2 - b(q_i - E_i)^2 - K - R^p(E_i - \bar{E})$$

Firm i assumes that $Q_{-i,t} = Q_{-i,t-1}$, where

$$Q_{-i} = \sum_{j=1, j\neq i}^{n} q_j$$

The first order conditions for profit maximization are

$$\frac{\partial \pi}{\partial q_i} = \alpha - \beta(q_i + Q_{-i,t-1}) - \beta q_i - 2aq_i - 2b(q_i - E_i) = 0 \tag{5.20}$$

$$\frac{\partial \pi}{\partial E_i} = 2b(q_i - E_i) - R^p = 0$$

Since we have assumed that firms are identical, emissions after trading will be $E_i = L/n$. Solving for q_i from (5.20) gives

$$q_i = \frac{2b(L/n) + \alpha - \beta Q_{-i,t-1}}{2\,(a + b + \beta)}$$

Also under imperfect competition a firm regulated through permit trading must cover the opportunity costs of emissions. Therefore, it must hold that

$$\pi_i = p(q_i + Q_{-i,t-1})q_i - aq_i^2 - b(q_i - E_i)^2 - K - R^p E_i \geq 0$$

The equilibrium number of firms in the market, n^* is the smallest number of firms for which it holds that $\sum_{i=1}^{n^*+1} \pi_i < 0$. This is found iteratively. Hence, in the model, the number of firms in every period is increased from 2 to the number where profits are lower than zero. Then the number of firms in the market is the latter number of firms minus 1.

Credit Trading and Relative Standards Also here, the analysis of credit trading and relative standards is identical. Therefore, I concentrate on credit trading. With credit trading, the profits of a firm become

$$\pi_i = p(Q)q_i - aq_i^2 - b(q_i - E_i)^2 - K - R^c(E_i - \bar{e}q_i)$$

where $\bar{e} = L/Q_{t-1}$. Firm i assumes that $Q_{-i,t} = Q_{-i,t-1}$, so that the first order conditions for profit maximization are

$$\frac{\partial \pi_i}{\partial q_i} = \alpha - \beta(q_i + Q_{-i,t-1}) - \beta q_i - 2aq_i - 2b(q_i - E_i) + R^c\bar{e} = 0$$

$$\frac{\partial \pi_i}{\partial E_i} = 2b(q_i - E_i) - R^c = 0$$

The output level of firm i in period t is then given by

$$q_i = \frac{\alpha - \beta Q_{-i,t-1}}{2\left(a + b\left(\bar{e} - 1\right)^2 + \beta\right)}$$

Also under credit trading, the number of firms in the market is found through iteration.

Absolute Standards The analysis of absolute standards is identical to the one of permit trading except for two points. In the first place, there is no market for quotas, so there is no permit price under absolute standards. This means that R^p should be replaced with a shadow price λ. Secondly, under absolute standards, the firm does not have to cover the opportunity costs of emissions. Hence, the profit condition becomes

$$\pi_i = p(q_i + Q_{-i,t-1})q_i - aq_i^2 - b(q_i - E_i)^2 - K \geq 0$$

Combined Trading As with perfect competition, we can combine the two systems. From the first order conditions for permit and credit trading, we can derive for the emission level per firm

$$E_i^p = \frac{-\left(R^p(a+b+\beta) + b\left(\beta Q^p_{-i,t-1} - \alpha\right)\right)}{2b\,(a+\beta)}$$

$$E_i^c = \frac{-\left(R^c(a+b(1-\bar{e})+\beta) + b\left(Q^c_{-i,t-1}\beta - \alpha\right)\right)}{2b\,(a+\beta)}$$

Additionally, we need a condition on the total amount of emissions in both systems and a condition that the emission quota price will be the same in both segments of the market:

$$n^c E^c + n^p E^p = n^p \bar{E}^p + n^c q^c \bar{e}^c$$

$$R^p = R^c = R$$

Using these to solve for the price of emission quotas, we find

$$R = -\frac{b\left(2an^p\bar{E} + n^c\,(\bar{e}-1)\left(\alpha - \beta Q^c_{-i,t-1}\right) + n^p\left(\beta Q^p_{-i,t-1} - \alpha + 2\bar{E}\beta\right)\right)}{a\,(n^c+n^p) + b\left(n^p + n^c(\bar{e}-1)^2\right) + \beta\,(n^c+n^p)}$$

The emission quota price can then be used in the first order conditions to solve for q_i^p and q_i^c. These are given by

$$q_i^p = \frac{\alpha - R - \beta Q^p_{-i,t-1}}{2(a+\beta)}$$

$$q_i^c = \frac{\alpha + R(\bar{e}-1) - \beta Q^c_{-i,t-1}}{2(a+\beta)}$$

5.4.2 Simulation results

Simulation results are reported in Figures 10-13. The first three figures gives some cases where the standards are set myopically. In Figure 12, permit and credit trading are combined, while in Figure 13 the optimal long-run standard is set from the onset of regulation. In all cases, the initial conditions under no regulation are the same, with $q^n = 7.14$, $E^n = 7.14$, $p^n = 21.43$, $n^n = 4$ and profits of 2.04 in every period. Total emissions without regulation are 28.57 and the government wants to reduce this amount by 30%, leading to a limit on emissions of $L = 20$. The figures show the index of output per firm (dotted line), product price (drawn line) and the number of firms (dashed line) where the no regulation inices are set to 100.

In a sense, one would expect more volatility in a market with oligopoly competition and Nash behavior than with perfect competition. The reason is that under these circumstances, any change will lead to reactions by the competitors. This is exacerbated by the assumption that firms set their output depending on their competitors' output in the previous period. This introduces a new lagged variable that can cause volatility. On the other hand however, changes in a oligopolistic market may be less pronounced and it is less likely that there will be changes in all variables in every period. For example, the number of firms may change as a result of the introduction of environmental regulation, but such a change often only occurs once or at most twice, at least under permit trading and absolute standards. This then has a dampening effect on the market.

These two forces, the one increasing volatility, the other decreasing it,

Figure 5.11: Imperfect Competition, Myopic Government

$a = 1,\ K = 100,\ \alpha = 50,\ \beta = 1$

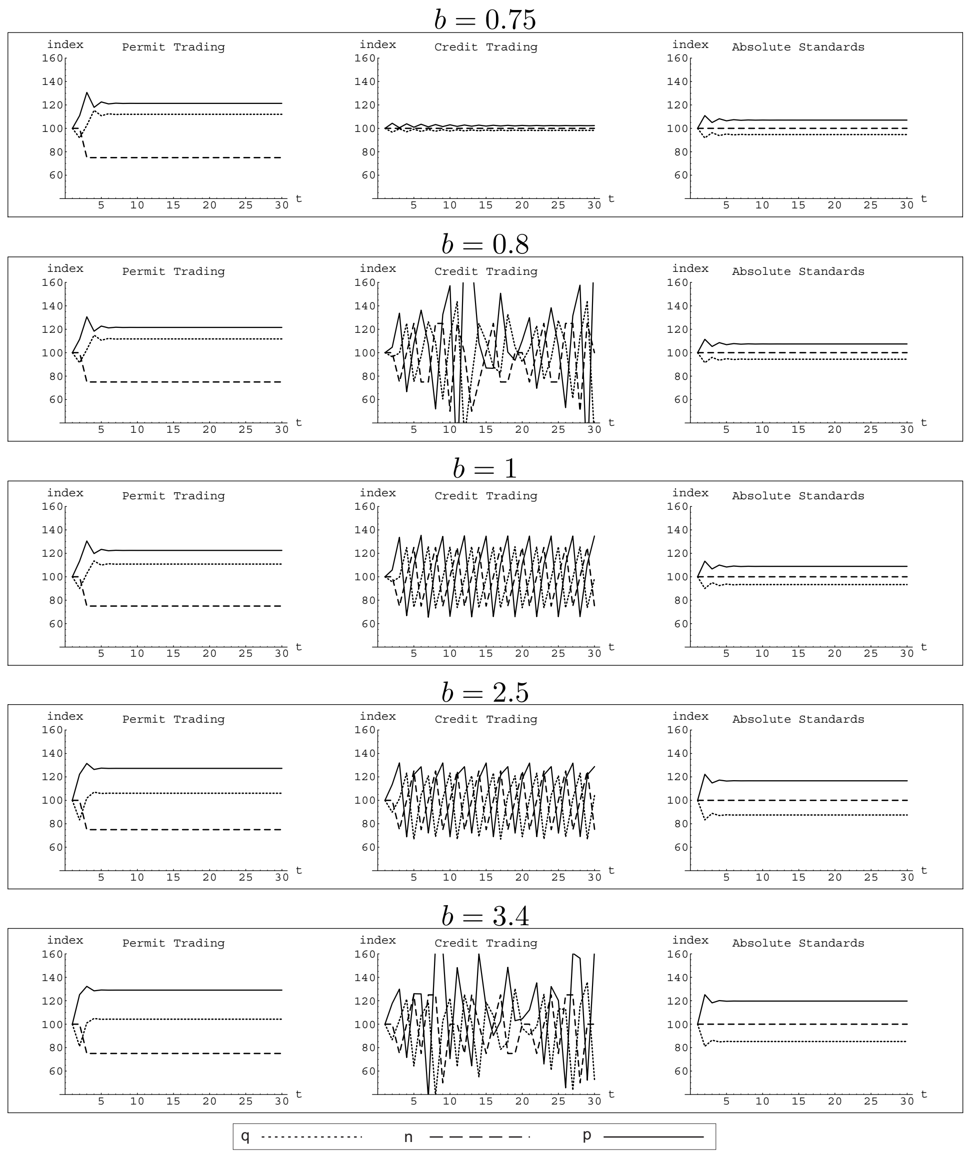
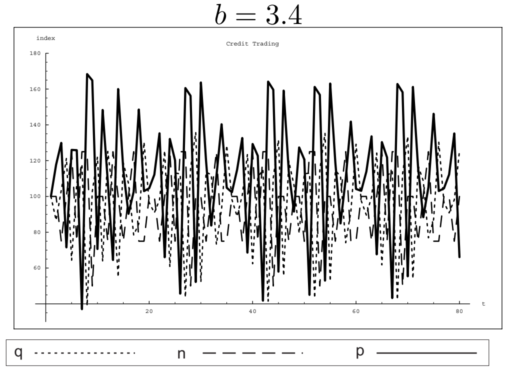


Figure 5.12: Imperfect Competition, Myopic Government

$a = 1,\ K = 100,\ \alpha = 50,\ \beta = 1$
$b = 3.4$



seem to compensate each other more or less since the general results of the analysis under imperfect competition are rather similar to those under perfect competition. As with perfect competition, the market is more likely to be volatile under credit trading than under permit trading. As Figure 10 shows, the system quickly comes to equilibrium under low levels of b. However, already with $b = 0.8$, the system seems to become chaotic under credit trading. Interestingly, a higher b at first leads to a more structured form of volatility, whereafter the system becomes more chaotic again at $b = 3.4$. In Figure 11, the case of $b = 3.4$ under credit trading is given again, but now for a longer time period. It is clear from this figure, that there is high volatility, but that there also is some sense of regularity in the system. In this case, real chaotic behavior could not be produced. But then, the model could not be solved for higher levels of b than 3.4.

Combining the two systems leads to some volatility in both the permit and credit sector. However, the system always seems to go to an equilibrium. Hence, the volatility of the credit trading scheme spills over to the permit trading scheme, but eventually, the system eases down.

With imperfect competition, setting the standard at its long-run equilibrium value from the start leads to less volatility in the market at lower levels

Figure 5.13: Imperfect Competition, Myopic Government, Combined Trading

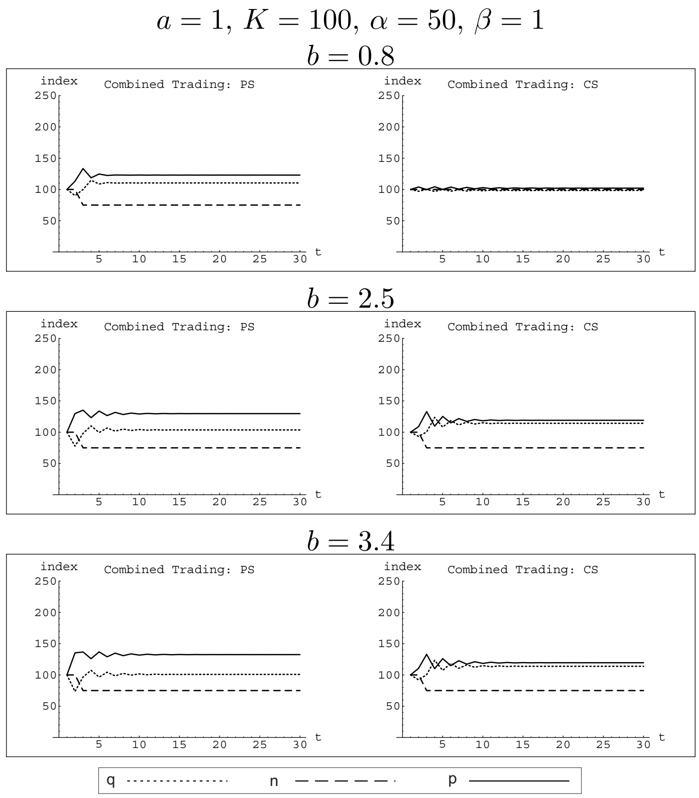
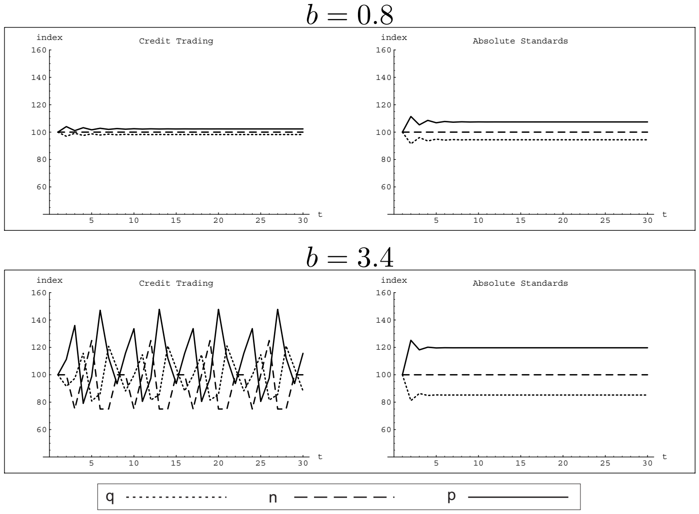


Figure 5.14: Imperfect Competition, Constant Standards

$a = 1$, $K = 100$, $\alpha = 50$, $\beta = 1$
$b = 0.8$



of b as can be seen from the case with $b = 0.8$ in Figures 10 and 13. However, at higher levels of b, the system becomes volatile again. This is a result from the interplay between the entry and exit of firms and the way firms set their production level. This shows that with imperfect competition, volatility can be a persistent phenomena under credit trading, even when the government sets a constant standard from the beginning of regulation. This in contrast to perfect competition where setting a constant standard always leads to a smooth adjustment to the new equilibrium, even with credit trading.

5.5 Conclusion

In the economic literature, the performance of instruments for environmental regulation is mostly judged by their efficiency. Sometimes political, read distributional, effects are considered too. This chapter takes into account that the economic impacts during the transition period from no regulation to the new equilibrium with regulation should be taken into account too. In particular the volatility of output, which is an indicator of fluctuations in employment, the price consumers pay for output and the number of firms since excessive entry and exit during the transition period are a waste the policy maker would rather want to avoid.

In the model resented, regular adjustment of standards can lead to volatility in the regulated industry when the instrument used is relative standards or credit trading. Such volatility is more likely to occur when demand is elastic, abatement costs are high and the emission reduction goal is rather ambitious. Swift entry and exit of firms increases the volatility with low elasticity of demand, but mitigates the level of volatility with high elasticity of demand. The volatility generated under credit trading in the dynamic model is due to the fact that there is a non-linear relationship between the relative standards in subsequent periods. With absolute standards, there is a linear relationship, while with permit trading, the government does not adjust the standard. The differences in how the standards are set explains why there is not much volatility with permit trading and constant standards, even when the government reacts myopically.

Of the types of regulation discussed in this chapter, constant relative standards are the conventional approach in the European Union (van der Laan 2002) and also in the USA. Frequent retrospective adjustment of standards does not occur. The possibility that total emissions will end up above or below the long run target is simply accepted. Absolute standards or emission ceilings are only applied by exception. In contrast, emissions trading in various forms may have the future. Several programs of credit trading exist in the USA and the UK. The USA was also the first in starting a permit trading program for SO_2 emissions. The EU has just launched a permit trading scheme for CO_2 emissions. From the point of view of policy relevance, a comparison of credit trading and permit trading programmes to assess their performances during the transition stage from no regulation to the new equilibrium with regulation in particular in terms of volatility therefore is in place.

In all simulations of permit trading under perfect competition the number of firms and product price increases or decreases smoothly. Only output per firm overshoots its long-run equilibrium in the first periods after the introduction of regulation, but subsequently adjusts smoothly. With imperfect competition the adjustment is generally somewhat less smoothly, but basically the same as with perfect competition. With perfect competition and constant standards, credit trading leads to an at least equally smooth adjustment at with permit trading. However, with imperfect competition credit trading can lead to volatility in the market, even when the standard is set at its long-run optimal level from the start of the program.

These results suggest that under perfect competition differences in pains of adjustment are not likely to play a role in the choice between credit and permit trading or constant standards. Volatility would then only be a problem when the government uses credit trading and frequently adjusts the underlying relative standard. However, with imperfect competition, credit trading may lead to higher adjustment costs, even when the government does not adjust the underlying relative standard. In that case, permit trading would be the better choice.

Chapter 6

Strategic Choice of International Emissions Trading Scheme in an Open Economy with Perfect Competition

6.1 Introduction

The Kyoto Protocol of 1997 allows international trade in greenhouse gas emissions between the countries that committed to an emission ceiling (the Annex B Countries). As the discussion within the EU has shown, there are many issues to be settled before an international emissions trading scheme can be implemented. One of the most important issues is what the basis for the national emissions trading schemes should be. Here, the choice is basically between a cap and trade system and a system based on relative standards (Boom 2001, Fischer 2003, Gielen et al. 2002 and chapter 4). In the first system, denoted as permit trading, there is a cap on total emissions, which is divided into permits that are distributed over the emissions sources, who are then allowed to trade them. In the second system, denoted as credit trading, firms are allowed to emit a certain amount of emissions per unit of output. This means that the total level of allowed emissions grandfathered to the firm is not fixed, but can change with output. Firms that stay below the standard can sell emission credits. It is not necessary for a firm to reduce emissions before it can issue credits, enabling purchasers to exceed the emission standard without offending compliance rules. Just as with permit trading, a firm can issue a credit if it expects to reduce emissions (see Boom and Nentjes 2003). As shown in chapter 4, the two schemes have a different impact on the industry. Output is higher under credit trading than under permit trading and if the total emission goal is the same under both schemes, marginal abatement costs will be higher under credit trading. Of these two schemes, permit trading is the most efficient and leads to the highest welfare when all emission sources are price takers both in the goods and in the emission quota markets.

Besides the choice between credit and permit trading, governments must decide whether or not to allow international emissions trading. The effect of opening up for international trading is that the price of emission quotas will change, which in turn will affect production within the country. If the regulated industry is small on a world scale, this is how far the analysis goes. A country will then always gain from allowing emissions trading since it will either save on abatement costs, or make a gain from the sale of permits. This is the classical case for emissions trading, both nationally and internationally. It also follows that the optimal international emissions trading scheme under these circumstances is permit trading.

However, countries can have market power in a good, even when their firms do not. In that case, the country can affect the price on the world market by altering domestic production through its policies. As will be clear from the description of permit and credit trading above, one such policy that potentially could affect the world market is environmental policy.

The main purpose of this chapter is to analyze whether countries have an incentive to choose their emissions trading scheme strategically when they have market power in the goods market. To this end, a partial equilibrium model with one industry is developed with perfect competition in both the goods and the emissions quota market. Although a country could have market power in the emissions quota market as well, this will be harder to obtain than market power in a good since several industries will be trading emission quotas together. In order to concentrate on the choice of instrument, it is assumed that the countries involved have committed to a cap on total domestic emissions. Several papers have discussed the effect of environmental policy on international trade and welfare, but not many papers discuss instrument choice of a country in such a setting with perfect competition in the goods market (see next section for an overview of the literature). This chapter differs from previous work in this area in that it compares instruments of environmental policy in their effect on the welfare of a country and in that it considers the choice between national and international emissions trading. The analysis shows that countries may have an incentive to distort international trade through the choice of emissions trading scheme and that in certain cases countries have an incentive *not* to allow international emissions trading.

In the next section a brief overview of previous, related work is given. In section 6.3 a partial equilibrium two-stage model is presented. In the first stage, the government decides which form of emissions trading to implement and whether or not to allow international emissions trading. In the second stage, firms maximize their profits under perfect competition while taking the choice of instrument by the government as given. As is usual in stage games, the two stages will be discussed in reverse order. In section 6.4, we give an analysis of the Nash equilibrium instrument choice in a two-country setting. The analysis is given for four scenarios which differ according to whether the international emissions quota price is lower or higher than the domestic price of the two countries. A summary and conclusions are given in section 6.5

6.2 Literature Review

In all the models discussed in this section it is assumed that firms operate in a market of perfect competition. One of the characteristics of such a market is that no single firm has an influence on the price of the good produced. However a country may be able to affect the price of a good. It will be able to do so when it produces a considerable part of total world output and when it implements a policy that affects all domestic firms in the sector.

Markusen (1975) develops a general equilibrium model of trade and transboundary pollution. In the model, there are two commodities, one of which causes pollution and the other, non-polluting, good is taken as the numeraire. There is no possibility for substitution among inputs or outputs so as to reduce emissions, nor is an abatement technology available. Therefore, the only method to reduce domestic pollution is by reducing production. Not only domestic production causes pollution in the home country, this is also the case with foreign production. However, the foreign country does not implement any environmental policy. The domestic government seeks to maximize welfare and has three instruments to do so; it can use a tariff on exports and imports, a production tax and a consumption subsidy. Markusen first determines the optimal tax structure, after which he analyzes the three cases where only one of these instruments can be used. Since the government has market power in both goods, it will try to manipulate relative prices such that the world market price of the exported good increases relative to the imported good. At the same time, the government wants to reduce both domestic and foreign pollution.

The first best tax structure can be achieved with any two of the three policy instruments. This is most easily seen for the combination of a production tax and a trade tax. The production tax is set at the usual level, where marginal abatement costs equal marginal social damage. The trade tax consists of two parts: a trade part and a pollution part. The trade part is the usual optimal tariff formula for the two-good case. If the polluting good is exported, the government will impose an export tax, while if it is imported, it will impose an import tariff. In that way, the government can always increase the price of the export good relative to the import good. The pollution part of the trade tax aims at reducing foreign pollution. This part is always positive. Hence, the domestic government will impose an import tariff if the polluting good is imported and an export subsidy when the good is exported.

Of the three cases where only one instrument can be used, the case with product taxes is the most interesting for our purpose. With only a production tax, the three components mentioned above all influence the level of the tax. First of all, domestic pollution calls for a positive tax. However, this production tax will cause the price to rise, which in turn encourages foreign production and thereby foreign pollution. Hence, with foreign pollution, the production tax will be lower than without foreign pollution. The third part is the already mentioned optimal tariff part. When the product is imported, domestic production should be subsidized, when it is exported, it should be taxed. The resulting tax (or subsidy) depends on the strengths of these three effects.

Krutilla (1991) analyzes a partial equilibrium model with only domestic pollution. Besides discussing pollution as a production externality, he also models the case where pollution is a consumption externality. Just as Markusen, Krutilla discusses the use of both an environmental tax and a tariff on the export or import of the good. Not surprisingly Krutilla arrives at the same conclusions as Markusen in the case of a production externality. The optimum can be reached by use of a Pigouvian tax on pollution and a tariff on exports or imports. When the tariff instrument cannot be used, the environmental tax is lower than the Pigouvian tax when the good is imported, while it is higher than the Pigouvian tax when the good is exported.

Dijkstra (1998) develops a partial equilibrium model similar to Krutilla (1991). Whereas in Markusen (1975) and Krutilla (1991) domestic pollution is variable and only taxation is considered, in Dijkstra domestic emissions are given, but governments can choose between several instruments of environmental policy. Furthermore, in Dijkstra (1998) abatement technologies are available, so that there no longer is a one on one relationship between production and pollution.

Dijkstra (1998) analyzes four cases: autarky, international trade without pollution, international trade and domestic pollution and international trade and global pollution. The model is a one-shot game of instrument choice between governments, where the first two cases are used as benchmarks. Dijkstra (1998) shows that there is no difference between the instruments of taxation, permit trading and firm-level emission ceilings. However, he does find a difference between these instruments and an emission standard per unit of product. The main reason for this is that with a standard per unit of product the producer will produce more than with the other instruments. Hence, in cases where welfare can be increased by higher production, standards per product outperform taxes. Dijkstra (1998) finds two such cases. Production is too low with emission taxes when a country imports the polluting good. This result comes about irrespective whether pollution is local or transboundary. A second case occurs only with transboundary pollution. Dijkstra assumes that the foreign country does not have any environmental policy. If the domestic country reduces emissions, domestic output declines and foreign output increases. The latter effect is unwanted because foreign output is more polluting than domestic output. Therefore, it would be better to have both low domestic emissions and high domestic output. This can be achieved with relative standards.

The model presented in the next section builds on the models discussed above, especially on Dijkstra (1998). The model extends previous work in that credit trading has never been considered in this setting before. The main contribution however is that international emissions trading, in alternative forms, permit trading and credit trading, is added to the analysis. The setting makes it possible to analyze instrument choice at the national and international level, and to determine whether it always is optimal for governments to allow international emissions trading. Like Dijkstra, but unlike Markusen and Krutilla I assume that the emission level in all relevant countries is fixed. In the context of climate change policy this assumption is relevant since countries have committed themselves to emission ceilings. Hence, there is no interplay between instrument choice and levels of emissions and we can concentrate on the choice of emissions trading scheme.

6.3 The Model

In this section, a model is presented with perfect competition in the goods and emission quota market. The good is traded internationally with producers located both in the home country and abroad. Firms have no influence on the price of the product or on the price of emission quotas. However, it is assumed that the country's output of the product is so large compared to total world production that the government can affect the product price by the environmental policy it implements. In the model, it is assumed that countries have no market power in the emissions quota market. The rationale for this is that international emissions trading will occur between firms from several industries from various countries. Therefore, it is harder to gain market power in the emissions quota market through the choice of instrument in an industry that to obtain market power in the market for a good. Essentially, the government has to make two choices: 1) which instrument of environmental policy to choose, where we limit the analysis to permit and credit trading, and 2) whether to restrict trading to national emission sources, or to allow international emissions trading between sources. The model is a two-stage model with the government moving first by choosing an instrument. In the second stage, firms maximize profits, while taking the choice of instrument as given. As is usual with stage games, stage two is analyzed before stage one.

There are n producers of a homogeneous good in the country, with n being large. Each firm maximizes its profits taking the price P as given. Costs are represented by $C(q, E)$, where q is production and E are emissions. The cost function has the following properties

$$C_q > 0, \quad C_E < 0, \quad C_{qq} \geq 0, \quad C_{EE} > 0, \quad C_{qE} < 0 \tag{6.1}$$

The government has set a limit on total emissions from the industry equal to L. In the following, it is assumed that the government has perfect information about the behavior of the firms. It is therefore always able to set the environmental policy such that the total limit on emissions is realized.

6.3.1 Stage Two: Firm behavior

In this section we analyze firm behavior. First, we deal with the case where the government implements national policies, but does not allow international emissions trading between private entities. Here we restrict the choice of national instrument to permit trading and credit trading. Permit trading is based on an absolute cap on emissions, while credit trading is based on relative standards that put a limit on emissions per unit of output. As Dijkstra (1999) shows, the outcome under permit trading is identical to that under taxes or absolute standards. Furthermore, the outcome under credit trading is identical to the outcome under relative standards. Hence, although the analysis is limited to only two instruments, results apply to other instruments as well. In the following we will show that credit trading leads to a higher output level and higher marginal abatement costs than permit trading.

Permit Trading. With permit trading, the ceiling that is placed on total domestic emissions is divided among the firms in the form of emission permits that give the right to emit a certain amount of the pollutant. The initial distribution of permits can either be for free (grandfathering) or through an auction, or a combination of the two. After the initial distribution, firms are free to trade the permits. Here, we assume that the permits are grandfathered. With permit trading, the firm's maximization problem becomes

$$\max_{q,E} \quad \Pi = Pq - C(q,E) - t(E - \bar{E}) \tag{6.2}$$

Here t is the domestic permit price and $\bar{E}$ is the initial allocation of permits, with $\bar{E} = L/n$. The first order conditions are

$$P = C_q \tag{6.3}$$

$$-C_E = t \tag{6.4}$$

These are the usual conditions under perfect competition; the firm equates marginal costs of production to the price of the product and also equates the marginal costs of emissions to the price of permits. The second order condition is given by

$$\mathbf{C_{xx}} = \begin{pmatrix} C_{qq} & C_{Eq} \\ C_{qE} & C_{EE} \end{pmatrix} \quad \text{is positive semidefinite} \tag{6.5}$$

This implies that the determinant is positive:

$$C_{EE}C_{qq} - C_{qE}^2 > 0 \tag{6.6}$$

The effect of a change in t on firm emissions can be found by differentiation of the first order conditions:

$$\frac{dq}{dt} = \frac{C_{qE}}{C_{EE}C_{qq} - C_{qE}^2} < 0 \tag{6.7}$$

The sign of (6.7) follows from (6.1) and (6.6).

Credit Trading. With credit trading, the government sets a relative standard $\bar{e}$ per unit of production, with $\bar{e} = L/nq$. Firms are allowed to sell credits if they can stay below the standard. The maximization problem of the firm becomes

$$\underset{q,E}{max} \quad \Pi = Pq - C(q,E) - r(E - \bar{e}q) \tag{6.8}$$

where r is the price of credits. The first order conditions are

$$P + r\bar{e} = C_q \tag{6.9}$$

$$-C_E = r \tag{6.10}$$

Combining the two first order conditions gives

$$P = C_q + \bar{e}C_E \tag{6.11}$$

Comparing (6.11) with (6.3), it is clear that production will be higher with relative targets than with permit trading at the same level of emissions. To see this, recall that $C_E < 0$ and $\bar{e} > 0$. Hence, the factor $\bar{e}C_E$ is negative and works as a subsidy on output (see Fischer (2001), Gielen et al. (2002) and chapter 4). The result is that the product price is lower under relative standards than under permit trading. This can only be the case when production is higher under relative standards than under permit trading.

Another result should also be noted. With relative standards, the marginal costs of abatement are higher than under permit trading. This result follows from the fact that total emissions are equal under the two instruments, while output is higher under relative standards. As given in (6.1), the marginal abatement costs is increasing in output for the same level of pollution. Hence, marginal costs of abatement will be higher with relative standards than with permit trading.

The effect of a change in r on output is given by

$$\frac{dq}{dr} = \frac{q\left(qC_{qE} + EC_{EE} + C_E\right)}{q^2\left(C_{qq}C_{EE} - C_{qE}^2\right) - C_E\left(qC_{qE} + EC_{EE}\right)} < 0 \tag{6.12}$$

To determine the sign of (6.12) we need to impose the following condition:

$$qC_{qE} + EC_{EE} < 0 \tag{6.13}$$

This condition ensures that under credit trading product price decreases with emissions (see Dijkstra (1999), p. 83 for a discussion). The sign of (6.12) then follows from (6.6) and (6.13).

International Emissions Trading As mentioned above, we assume that neither firms nor governments have market power in the market for emission quotas. This means that the international emission quota price is given for firms. Denote the international quota price by T. The only change in the analysis for the two instruments then is that t and r are replaced by T.

6.3.2 Stage One: Choice of Emissions Trading Scheme

We now turn to the instrument choice of a country. The case analyzed is the one where all relevant countries have committed to a certain emission goal. The emission goal of the home country is given by L_h. The assumption that all relevant countries have committed to an emission ceiling makes that the emission levels are fixed, and hence, that countries do not have an incentive to manipulate the level of emissions.

Since now we turn to the level of the country and not the firm or industry, we have to adapt the notation slightly. In the following, h denotes the domestic country, while f denotes the remainder of the world. Then q_i, $i = h, f$ denotes output of an individual firm and $Q_h = \sum q_h$ denotes total domestic production. The home country is large enough to influence the price of the product on the world market. This also implies that a change in domestic production leads to a change in foreign production. Total foreign production is denoted by $Q_f(P(y), I_f)$, where I_f is the foreign policy choice. It must hold that

$$-1 < \partial Q_f / \partial Q_h < 0 \quad \Leftrightarrow \quad 0 < \frac{dy}{dQ_h} < 1 \tag{6.14}$$

where y is total world consumption, which is equal to total world output. Equation (6.14) says that when domestic output increases, foreign producers reduce their output, but not by as much as the original increase of output by the home country. The overall result is that total output is increased but by less than the initial increase in output. This condition is needed to ensure stability of the Nash equilibrium.

In the following, all consumers and all firms in all countries are assumed to be identical. We denote by μ_h the proportion of identical consumers in the home country.

No international emissions trading

We first analyze the case where international emissions trading is not possible, neither between firms nor between governments. The welfare of the domestic country is given by

$$W = \mu_h \int_o^y P(y)dy - P(y)\mu_h y + P(y)n_h q_h - n_h C(q_h, E_h) \tag{6.15}$$

The first two terms on the RHS of equation (6.15) give the domestic consumers' surplus. The last two terms give the producers' surplus. Differentiating equation (6.15) with respect to q_h gives

$$\frac{\partial W}{\partial q_h} = n_h \left(P - C_{q_h}\right) + P' \frac{\partial y}{\partial q_h} \left(n_h q_h - \mu_h y\right) = 0 \tag{6.16}$$

The first term gives the aggregate difference between product price and marginal production costs, while the second term gives the trade balance in the product times the effect of a change in production on the product price. As already mentioned in section 6.2, the optimal policy would normally consist of an import tariff or export tax combined with an emission tax or national permit trading. However, here we assume that the government cannot use an import tariff or export tax. Therefore, it can only affect domestic welfare through the choice of environmental policy instrument.

In two special cases it is possible for the government to obtain maximum welfare. A first instance is when the implementation of permit trading leads to autarky. This can be seen by setting the term for the domestic excess supply, $n_h q_h - \mu_h y$, equal to zero. The result is equivalent to equation (6.3), which gives the profit maximizing level of production in the case of permit trading. The second case is when the use of credit trading leads to a trade deficit in the good equal to $n_h q_h - \mu_h y = -n_h \bar{e}_h C_{E_h} / P' \frac{\partial y}{\partial q_h}$. This follows from (6.11), which shows that $P - C_{q_h} = \bar{e}_h C_{E_h} < 0$ with credit trading, and inserting this in (6.16). The intuition here is that through the use of credit trading the importing country succeeds in bringing down the world market price, compared to the use of permit trading, by so much that it achieves the optimal increase in consumer surplus minus producer surplus.

Suppose that permit trading does not lead to autarky in the product, but to an export of the product. We now find $P = C_{q_h}$ and $n_h q_h > \mu_h y$. Equation (6.16) now becomes negative and welfare would be higher with a lower level of production. However, production should not be so low that the country achieves autarky. With autarky, $P > C_{q_h}$ and $n_h q_h = \mu_h y$ and welfare would be higher with a higher production level. This shows that when permit trading leads to net exports of the product, optimal welfare is reached with a lower production level, but the country should still be an exporter. The reason for this result is that when the country is an exporter, the producers' surplus is more important for the welfare of the country than the consumers' surplus. By reducing output, the country can increase the price of the product, increasing profits for its own firms. In the case where permit trading leads to a net export of the good, permit trading is not optimal since output is too large. However, the only alternative is credit trading, which leads to even higher output. Therefore, permit trading is the best choice under the given circumstances.

We now turn to the case where the imposition of permit trading leads to an import deficit in the good. Then, $n_h q_h < \mu_h y$ and $P = C_{q_h}$. Now production is lower than optimal. Hence, the government would want to increase production. This can be done by using credit trading. In that case $P < C_{q_h}$. However, credit trading may lead to higher than optimal production. It may even overshoot optimal production by so much that the government will still prefer the underproduction of permit trading.

To see when the use of credit trading is likely to cause too much production, consider the impact of the strictness of regulation on the size of the term $P - C_{q_h}$. When the country uses credit trading, $P - C_{q_h} = \bar{e} C_E < 0$. When $\bar{e}$ is very large, environmental policy is not binding, $C_E = 0$ and the output level under credit trading is equal to that under permit trading. Then, as environmental policy becomes binding, $-C_E$ rises and $\bar{e}$ falls. Initially, the term $-\bar{e} C_E$ will increase, but at some level of environmental policy it will reach a peak and will fall again with stricter environmental policy. Finally, when $\bar{e} = 0$, output under the two forms for regulation is identical again. Thus, credit trading reduces output price most relative to the output price under permit trading with intermediate levels of environmental policy. Consequently, the difference in output levels is largest in this interval and credit trading is most likely to overshoot the mark by leading to too much production compared to permit trading. Importing countries are then more likely to implement credit trading when environmental policy is either very weak or very strict.

We can summarize these results as follows:

Proposition 25 *When international emissions trading is not possible, domestic permit trading is the optimal instrument when it leads to a trade surplus or a small trade deficit in the good. When the use of domestic permit trading leads to a large trade deficit in the good, the government prefers to use domestic credit trading.*

International emissions trading.

We now turn to the situation where firms are allowed to trade emission quotas internationally. As mentioned before, we assume that neither the firms, nor the country have market power in the market for emission quotas. With international emissions trading, welfare of a country consists of the consumers' surplus, the producers' surplus and the proceeds from emissions trading

$$W = \mu_h \int_0^y P(y)dy + P(y)\left[n_h q_h - \mu_h y\right] - n_h C(q_h, E_h) + n_h T\left(\bar{E}_h - E_h\right)$$

Differentiating with respect to q_h yields

$$n_h\left(P - C_q\right) + P' \frac{\partial y}{\partial q_h}\left(n_h q_h - \mu_h y\right) = 0 \tag{6.17}$$

Hence, the optimization problem of the government is essentially the same as when there is no international emissions trading. This implies that the analysis for preference of instrument as given above also holds here when the only choice is between international permit and international credit trading.

Proposition 26 *Suppose a country engages in international emissions trading. Then, international permit trading is the optimal instrument when it leads to a trade surplus or a small trade deficit in the good. When the use of international permit trading leads to a large trade deficit, the country prefers to use international credit trading.*

Proof The first order condition for welfare maximization with international emissions trading, equation (6.17), is identical to (6.16), so that the proposition follows from the analysis in section 6.3.2. □

There is however a difference between the situation with domestic trading and the one with international trading. With international trading, the switch from permit to credit trading leads to a larger increase in output than with domestic trading. This is because with credit trading, the country will buy more (or sell less) emission quotas in the international market than with permit trading. We then find that in the case where the (importing) country wants to increase production but credit trading leads to too much production, it would be less inclined to choose credit trading with international emissions trading.

To analyze the shift to international emissions trading, we will make use of the mean value theorem (see Sydsæter and Hammond (1995), p. 222 and Brander and Spencer (1983)). In particular, let $f(x)$ be a continuous and differentiable function in the interval (a, b). Then there exists an interior point α in (a, b) such that

$$\Delta f \equiv f(b) - f(a) = f'(\alpha)(b - a) \tag{6.18}$$

where $f'(\alpha)$ is the differential of f evaluated at α, with $\alpha = a + \beta(b - a)$ for some $\beta \in (0, 1)$.

The shift from national emissions trading to international emissions trading can be viewed as a change in the price of emissions quotas. Using (6.18), the effect of such a shift on welfare can be given as

$$\Delta W = \frac{dW}{d\tau}\,(T - \tau) \tag{6.19}$$

where τ is the domestic emission quota price and $dW/d\tau$ is evaluated at some point between τ and T. Writing this out and substituting (6.4) or (6.10) gives

$$\Delta W = \left[n_h \frac{dq_h}{d\tau} \left(P - C_{q_h} \right) + P_\tau \left(n_h q_h - \mu_h y \right) + n_h \left(\bar{E}_h - E_h \right) \right] (T - \tau) \tag{6.20}$$

The first term on the RHS of (6.20) gives the difference between the price and the marginal production costs times the change in total output. The second term gives the trade balance in the product times the change in the product price due to a change in output. The third term gives revenue from emissions trading. In the following, we will analyze whether a shift to international emissions trading leads to higher or lower welfare for each of the two instruments separately.

Permit Trading. With permit trading, $P = C_{q_h}$ from (6.3) and equation (6.20) diminishes to

$$\Delta W = \left[P_\tau \left(n_h q_h - \mu_h y \right) + n_h \left(\bar{E}_h - E_h \right) \right] (T - \tau) \tag{6.21}$$

Note that because of the shift to international emissions trading, the balance of trade in the good may change. This change is given by

$$\frac{d(n_h q_h - \mu_h y)}{dn_h q_h} = 1 - \mu_h \frac{dy}{dn_h q_h} > 0$$

The inequality follows from (6.14) and $\mu_h < 1$.

Basically, there are four possible cases depending on the balance of trade in the product and on the world price of permits. An overview of these four cases is given in Table 6.1. In the first case, the country is an exporter of the good and the world price of permits is higher than the domestic price. In this case, the country will export permits, hence $\left(\bar{E}_h - E_h \right) > 0$. The higher permit price will give a decrease in production and this will raise the price of the product. The overall effect is that equation (6.21) will be positive. Hence, the shift to international emissions trading leads to a welfare gain. It has to be noted though that this only holds as long as the country remains a net exporter of the good. If production is decreased so much because of the rise in the permit price that the country becomes a net importer, welfare may decrease.

In the second case, the country also exports the good, but the world price of permits is lower than the domestic price. Being an exporter, there is an incentive for the country to increase production and therefore the price of the product decreases. Furthermore, because of the lower world permit price, the country buys emission quotas. In this case, the first term in square brackets in (6.21) is positive, while the second term is negative. Welfare decreases because the price of the product decreases, while an increase is needed, but welfare increases because of the trade in emissions. If the gains from emissions trading are low, the country may experience a loss in welfare when it shifts to international emissions trading. However, the gain from emissions trading can be so large as to outweigh the negative effect from a decrease in the product price. In all, the total effect is ambiguous.

The third case consist of the country being an importer of the good and a seller of permits. Also here, the sign of equation (6.21) becomes ambiguous. The result of the higher world price of permits is a reduction in production. However, an increase in production is wanted. On the other hand, the country exports permits, which leads to higher welfare. This is indicated by the positive sign of the second term. It now depends on the size of the two effects whether welfare is increased as a result of allowing international emissions trading.

In the fourth case, the country is an importer of the good and $T < t$. The country becomes an importer of emission quotas, which leads to an increase in production and a decrease in the price of the good. Both terms in (6.21) point in the direction of an increase in welfare. However, the increase in production may be so large that the country becomes an exporter of the good. In that case, welfare may decrease. However, since the country always gains directly from emissions trading, the production effect needs to be very large indeed for welfare to decline.

Table 6.1: Effect of a shift from national to international permit trading

case	$T-t$	$(n_h q_h - \mu_h y)$	$(E_h - \bar{E}_h)$	q_h	P	Welfare
1	$+$	$+$	$-$	$\downarrow$	$\uparrow$	Increase
2	$-$	$+$	$+$	$\uparrow$	$\downarrow$	Ambiguous
3	$+$	$-$	$-$	$\downarrow$	$\uparrow$	Ambiguous
4	$-$	$-$	$+$	$\uparrow$	$\downarrow$	Increase

Credit Trading. With credit trading $P - C_q = \bar{e}C_E < 0$, and equation (6.20) holds unchanged. Also with credit trading, there are four possible cases, depending on the sign of $(n_h q_h - \mu_h y)$, and on whether T is larger or smaller than r.

The only difference with the cases given under permit trading is that the use of credit trading leads to a distortion given by $P - C_q = \bar{e}C_E < 0$. When joining international emissions trading, output will be affected and so will the size of the distortion. When $T < r$, output will increase with a shift to international emissions trading. In this case, the distortion will increase, which has a negative impact on welfare. When $T > r$ output and the distortion will decrease, which has a positive impact on welfare. The implication is that when $T < r$ the shift to international emissions trading is less likely to lead to a welfare increase, while the reverse is the case when $T > r$. There is now only one case in which the shift to international emissions trading leads to an unambiguous increase in welfare. This is in case 1 when the country is an exporter of the good and $T > r$. However, it is unlikely that the distortion is larger than the gain from emissions trading. Thus we assume that in case 4 in Table 6.2, the shift to international emissions trading will still lead to an increase in welfare.

We can summarize one of the results from this discussion as follows

Proposition 27 *Given the instrument of environmental policy, a shift to international emissions trading does not always lead to an increase in welfare.*

Table 6.2: Effect of a shift from national to international credit trading

case	$T-r$	$(n_h q_h - \mu_h y)$	$(E_h - \bar{E}_h)$	q_h	P	Welfare
1	+	+	−	↓	↑	Increase
2	−	+	+	↑	↓	Decrease (amb.)
3	+	−	−	↓	↑	Increase (amb.)
4	−	−	+	↑	↓	Increase

6.4 Instrument Choice with Two Countries

In this section we will derive the Nash equilibrium of instrument choice when only two countries are involved in the production and consumption of the good. The two countries are called the home (or domestic) country h and the foreign country f. We uphold the assumption that there is an international emissions market on which the two countries have no influence. Analyzing the game for all possible equilibria under all possible circumstances leads to a myriad of possible equilibria and makes the analysis intractable. Therefore, we present some scenarios that should cover the most likely possibilities. In all scenarios, it is assumed that the two countries are identical in all aspects, except for two. First of all, we assume that the proportion of consumers living in the home country μ_h is smaller than the proportion of consumers living in the foreign country μ_f, with $0 \leq \mu_h, \mu_f \leq 1$ and $\mu_h + \mu_f = 1$. This ensures that with identical instrument choice and emission ceilings, the home country exports the good, while the foreign country imports the good. Furthermore, the emission ceilings in the two countries can be different, so that the domestic emission quota price in the two countries may differ.

To make the analysis easier, we will use the following notation: *ptd* and *ctd* stand for domestic permit and credit trading respectively, while *pti* and *cti* stand for international permit and credit trading respectively.

6.4.1 Scenario 1: $T < t_h(ptd, ptd) = t_f(ptd, ptd)$

In Scenario 1, we assume that the emission limit for the two countries is identical. This implies that when the countries choose the same instrument,

		Foreign country			
		ptd	pti	ctd	cti
	ptd	X	X	X	X
Home	pti	X	X	X	X
country	ctd		X	X	X
	cti			X	X

Table 6.3: Nash Equilibria in Scenario 1

their marginal abatement costs are identical. Furthermore, we assume in this case that $T < t_h(ptd, ptd) = t_f(ptd, ptd)$, so that both countries become buyers of emission quotas when they shift to international emissions trading. This shift will lead to an increase in production in both countries. In this case, when both countries choose the same instrument, country h is always the exporter, while country f is always the importer.

The possible Nash equilibria for Scenario 1 are shown in Table 6.3. Both countries may use any of the possible instruments in a Nash equilibrium. However, there are some combinations of instruments that do not constitute a Nash equilibrium.

First, when country f chooses *ptd*, country h is always the exporter of the good. It will then choose *ptd* or *pti* if the direct gain from international emissions trading is larger than the negative effect from the increase in output.

When country f chooses international permit trading, it is no longer certain that country h will be the exporter of the good. Since $T < t_h = t_f$, a shift to international permit trading by the foreign country will increase its output, which may lead to a trade surplus in the good. If country h still is the exporter, it will still prefer *ptd* or *pti*. However, if it becomes the importer, the home country may benefit from a shift to credit trading. Note first that *cti* never can be an optimal choice, because this would make it an exporter, and the country would benefit from a shift to *pti* where output is lower, but country h still is the exporter. Country h may however also choose *ctd*. As long as this still leads to a large import of the good, this may be optimal. But at the same time, a shift to *pti* will make country h the exporter.

When country f uses credit trading, output in the foreign country increases and the country may become the exporter of the good. When this is not the case, but country f remains the importer and country h the exporter when h uses credit trading, the analysis given in Section 6.3.2 and above shows that the home country will prefer *ptd* or *pti*. When country h becomes an importer when it uses permit trading, it may now prefer some form of credit trading when the import with permit trading is large. Note that this switch to credit trading may make country h the exporter again. However, even when it exports with credit trading, this instrument may be the best choice. The reason is that a switch to permit trading will make it the importer, but this is not optimal either, hence it is uncertain which instrument gives highest welfare in this case.

We now turn to the analysis of the optimal instrument choice by country f. When both countries use identical instruments, country f imports the good. From Section 6.3.2 we know that the country then has an incentive to increase production. However, switching to credit trading can lead to too much production and even to a trade surplus in the good. Furthermore, a shift to international emissions trading leads to a direct gain from trading, and since $T < t_f$ also to an increase in output.

Using the analysis of section 6.3.2, we can however draw a rather clear picture of when country f will use which instrument. Recall from section 6.3.2 that a country will use credit trading only when it is a large importer of the good. If it is a small importer, or even an exporter, it will prefer permit trading. This implies that if it is a large importer of the good, the country will prefer either domestic or international credit trading. The shift to international credit trading has both positive and negative effects. It will lead to a direct gain from emissions trading and an increase in production. The latter effect causes an increase in the distortion caused by credit trading (given by $\bar{e}C_E$), but also an increase in output as is wanted. However, since $T < t_f$ the shift to international credit trading may lead to a too large increase in output. So international credit trading will only be welfare

		Foreign country			
		ptd	pti	ctd	cti
	ptd	X		X	X
Home	pti	X	X	X	X
country	ctd			X	X
	cti	X		X	X

Table 6.4: Nash Equilibria in Scenario 2

improving if output does not increase by too much and when the production distortion does not become too big.

6.4.2 Scenario 2: $T > r_h(ctd, ctd) = r_f(ctd, ctd)$

In the second scenario, we still assume that the emission limit for the two countries is identical, so that when the countries choose the same instrument, their marginal abatement costs are identical. However, in this case we assume that $T > r_h(ctd, ctd) = r_f(ctd, ctd)$, so that both countries become sellers of emission quotas when they shift to international emissions trading. This shift will lead to a decrease in production in both countries. Again, when both countries choose the same instrument, country h is always the exporter, while country f is always the importer. The possible Nash equilibria for this scenario are given in Table 6.4.

We start with the optimal instrument choice of country h. When country f uses *pti*, country h is always the exporter. In this case, it is optimal for h to choose *pti*, because this leads to the smallest possible output, but h still exports. When country f chooses *ptd*, the outcome is less clear. If country h chooses *ptd* or *ctd* it will be the exporter, in which case h will prefer *ptd*. However, it may be better for country h to choose *pti* since this gives a direct gain from trading and lower production. Even when this shift makes h the importer it may increase its welfare when the gain from trading is large enough. It is even conceivable that h will choose *cti* if it has a large trade deficit with *pti*. This choice would be optimal if the direct gain from emissions trading is very large, but the shift to international trading leads

		Foreign country			
		ptd	pti	ctd	cti
	ptd	X	X	X	X
Home	pti	X	X	X	X
country	ctd	X	X	X	X
	cti	X		X	X

Table 6.5: Nash Equilibria in Scenario 3

to a large trade deficit in the good. In that case *pti* would lead to too large a deficit and *cti* would be better.

When country f chooses some form of credit trading, we can use the same arguments as used in Scenario 1 to show that country h may choose permit or credit trading, dependent on the situation. Since country f can be an importer with every instrument choice, the analysis under Scenario 1 still holds for this country.

6.4.3 Scenario 3: $t_h(ptd, ctd) > T > r_f(ptd, ctd)$

In this scenario, we assume that the emission ceilings are set such that $t_h(ptd, ctd) > T > r_f(ptd, ctd)$. This implies that no matter which domestic instrument the two countries set, the home country is a buyer of emission quotas, while the foreign country is a seller. For the home country, a shift to international emissions trading results in an increase in production and, ceteris paribus, an increase in exports. For the foreign country, such a shift will lead to a decrease in production and an increase in imports.

The possible Nash equilibria for scenario 1 are given in Table 6.5. Basically, both countries can choose all instruments in equilibrium.

In this case, country h will always be the exporter when both countries choose *pti* or *cti* or when h chooses *cti* and f chooses *pti*. In all other cases, country h may become the importer of the good. To see this, suppose that μ_h is not much lower than μ_f, while environmental policy is much more strict in country h than in country f. Then production in country h may become so low that it becomes an importer, even if it uses domestic credit trading or

		Foreign country			
		ptd	pti	ctd	cti
	ptd			X	X
Home	pti	X	X	X	X
country	ctd			X	X
	cti			X	X

Table 6.6: Nash Equilibria in Scenario 4

international permit trading. In these cases, we can use the analysis given under Scenario 1 for country f to show that country h will prefer permit trading when this leads to a small import or export of the good, while it will prefer credit trading when the use of permit trading (international or domestic) leads to large imports. This may imply that the country becomes an exporter of the good again. Although credit trading is not the optimal choice for an exporter, it may still be a best choice since a shift to permit trading will make it an importer, which is not optimal either. However, the outcome (cti_h, pti_f) cannot be a Nash equilibrium. To see this, note that when (pti_h, pti_f) is used, country h is the exporter of the good. Then it wants to lower its output, but *cti* would lead to an increase in output. Thus, country h prefers *pti* to *cti* when country f uses *pti*.

Country f can be the importer under any choice of instrument. Therefore, we can apply the analysis as given under Scenario 1 to show that it can choose any of the available instruments in equilibrium.

6.4.4 Scenario 4: $r_h(ctd, ptd) < T < t_f(ctd, ptd)$

In the fourth scenario we assume that the emission limits are such that $r_h(ctd, ptd) < T < t_f(ctd, ptd)$ so that country h becomes a seller and country f a buyer of emission quotas when they shift to international emissions trading. Such a shift will then cause a reduction in output in the home country and an increase in production in the foreign country.

The possible Nash equilibria for this scenario are given in Table 6.6. The home country is an exporter when both countries use some form of permit trading, and when the home country uses some form of credit trading. However, when country f uses some form of credit trading, it may become the exporter when country h uses some form of permit trading. To see this, note first that credit trading leads to higher production than permit trading. Hence, even though the permit price in country h is lower than the credit price in country f, country f may still produce more than country h. Then, if μ_h is close enough to μ_f, country $f$may become the exporter. This holds even stronger under international than under domestic credit trading, since in the latter case, output in country f will be larger.

The analysis is then rather straightforward for country h. When country f chooses international or domestic permit trading, country h will choose *pti*. By choosing *pti*, country h has the lowest possible output, but is still the exporter. However, when country f chooses some form of credit trading, country h may choose any of the available instruments. If it exports when it uses domestic or international permit trading, then this will be the optimal choice for h. However, if it imports when it uses permit trading, a shift to credit trading may be optimal, even if this shift makes it an exporter of the good again.

Since country f may be the importer under all choices of instrument, we can use the analysis given under Scenario 1 to show that all possible instruments may be an equilibrium choice.

In the previous sections, we have shown that when a country exports the good, it can increase its welfare by increasing the producer surplus, even though that diminishes the consumer surplus somewhat. Since permit trading leads to lower output than credit trading, one would expect that an exporter always prefers to use permit trading. For the importer, a somewhat similar reasoning holds. It would like to increase the consumer surplus, even if that diminishes the producer surplus. However, instrument choice for an importer is more complex than for an exporter. Credit trading leads to more production than permit trading and therefore seems the logical choice for an importer. But credit trading may lead to too much production, giving lower welfare. Hence the importer will prefer permit trading when it is a small importer.

The scenarios given in the current section partially confirm these expectations. In many cases, the exporter chooses domestic or international permit trading, while for an importer the choice depends on the size of the imports of the good. But it also possible that the exporter of the good chooses credit trading in the Nash equilibrium. This can happen when the country would become a large importer if it used another instrument. Normally in this case the other country also uses some form of credit trading. Hence, a Nash equilibrium where both the importer and the exporter use credit trading is possible.

6.5 Conclusions

In this chapter, a model of strategic choice of emissions trading scheme was presented with the assumption that the countries involved have committed to a certain overall emission target. Countries can either choose to implement permit trading, which is based on a cap on emissions per firm, or credit trading, which is based on relative standards per unit of output. The two schemes have a different impact on the regulated industry, with credit trading leading to a higher output level and higher marginal abatement costs. Furthermore, the countries must choose whether or not to allow their firms to participate in international emissions trading.

The main conclusions are that countries that can influence the world market price of a good and aim at maximization of national welfare have an incentive to choose their emissions trading scheme strategically and that in some cases, countries are better off when they do not participate in international emissions trading. The outcome depends on whether the country is an importer of the good, whether the world price for emission quotas is lower or higher than the domestic price and on how large the gain from international emissions trading is.

In general, when a country exports the good, the country's welfare is maximized by increasing the producer surplus even though that diminishes the consumer surplus somewhat. Therefore, the government wants to reduce output to raise the world price of the good and thereby increase firm profits. The best choice of a national instrument to realize the emission target and maximize welfare in this case is permit trading since it leads to a lower production level than credit trading. When the country imports the good, welfare can be maximized by increasing the country's consumer surplus even though some producer surplus has to be sacrificed. This can be achieved by lowering the world price of the product. Since credit trading cause a lower rise in product prices than permit trading, the country will often prefer a national credit scheme. However, credit trading can also lead to a too large increase in output, turning the importer into an exporter. In those cases, the importer will prefer to uses permit trading.

It should be noted that strategic choice of permit trading is equal to the non-strategic optimal choice of instrument. That is, a choice of permit trading by all countries leads to the global optimal outcome. In contrast, strategic choice of credit trading by an importer decreases world prices for price taking export countries that apply permit trading. The fall in world prices created by the importing country decreases the producer surplus and welfare in exporting countries. The introduction of credit trading for strategic reasons by an import country therefore is an example of a 'beggar my neighbor' policy.

Whether or not a country wants to allow international emissions trading for its firms depends mainly on two things: the world price of emission quotas relative to the domestic price and the size of the gain from emissions trading. When the country becomes a seller of emission quotas, either permits or credits, it will have to increase its abatement efforts, which will raise the marginal cost of output and consequently the price of output. The quantity produced and sold thereby decreases. This increases welfare when the country is an exporter of the good. It has a double benefit: from selling emission quotas and from having higher profits from exporting output.

One can conclude that an exporting country normally prefers domestic permit trading for strategic reasons and is willing to participate in international emissions trading if it expects to be a seller on the international market. However, if the exporting country is going to be a buyer on the international permit market, the result will be a decrease in product price which is not in its interest. The choice then depends on whether the gain from international emissions trading exceeds the fall in monopolistic profit on the product market. If not, the exporting country prefers not to participate in international emissions trading as a buyer.

The same type of reasoning leads to the conclusion that an importing country for strategic reasons will participate in international emissions trading when it expects to be a buyer of credits. When it becomes a seller, it will participate only when the gain from international emissions trading exceeds the decrease of consumer surplus due to higher product prices.

So in general it holds that an exporting country wants to use permit trading, while an importing country will want to use credit trading when it is a large importer and permit trading when it is a small importer. However, it is possible that both countries simultaneously choose credit trading. This happens when the exporting country would become a large importer if it chose another instrument.

Chapter 7

Strategic Choice of Domestic Environmental Policy Instrument and International Emissions Trading Scheme in an Open Economy with Imperfect Competition

7.1 Introduction

Many countries are currently implementing measures to reduce emissions of greenhouse gases. This may either be to comply with the Kyoto Protocol, or for those outside the agreement to reduce emissions as domestic policy. One of the central questions here is how to reduce emissions, i.e., which instrument to choose. This choice is further complicated by the possibility of international emissions trading. When all markets are perfectly competitive and governments have no market power either, the choice of instrument is rather easy. International emissions trading based on emission ceilings will maximize welfare for all countries involved. However, when countries or firms have market power in some markets, the choice of instrument becomes less straightforward.

The previous chapter analyzed the strategic choice of emissions trading scheme for the case of perfect international competition when countries have market power. Here it was found that the preference for emissions trading scheme depends on whether a country is an importer or an exporter of the good. An exporter wants to lower domestic production, while an importer wants to expand production. Since permit trading leads to a lower production level than credit trading, exporting countries generally prefer permit trading, while importers prefer credit trading. Whether or not a country wants to engage in international emissions trading depends on whether it becomes a seller or buyer of emission quotas. A country that sells quotas will contract domestic production, while a buyer will expand production. Depending on which is compatible with domestic preferences, a country may prefer to allow private international emissions trading. However, it may also be the case that the country prefers *not* to engage in international emissions trading.

With imperfect competition in the goods market, other forces come into play. Now the firms are engaged in a strategic game where market share is an important factor in determining profits. Furthermore, imperfect competition leads to lower output than perfect competition. If the country also consumes the good, it may therefore have an incentive to increase production. These factors make that preferences for both national instrument and international emissions trading scheme may be different with imperfect from what they are with perfect competition.

Other papers have discussed strategic choice of environmental policy and instrument choice in an international setting (see next section for an overview). However, only a few discuss relative standards and almost none discuss credit trading. Furthermore, when these instruments are considered, only the case of perfect competition is discussed.

In this chapter I will analyze the optimal choice of national instrument and international emissions trading scheme by governments when there is imperfect and international competition in the market for the output. More precisely, I present a partial equilibrium model of a market with two firms, producing a homogeneous good, each located in a different country. At the national level, governments can choose between emission ceilings and relative standards, while at the international level they can choose between permit and credit trading and no international emissions trading.

The chapter is organized as follows. In the next section, an overview of related literature is given. The model is discussed in section 7.3. First I will analyze the case without international emissions trading. Here the government can choose between emission ceilings and relative standards. It will be shown that the government always wants to increase production above the level reached with emission ceilings. After that, in subsection 7.3.2, the choice of international emissions trading scheme is discussed. The choice between schemes is more or less the same as that between national instruments, but with a change in the (shadow) price of emissions. However, it is shown that in certain cases, especially when the country becomes a seller of emission quotas, countries may prefer not to engage in international emissions trading. Conclusions are given in section 7.4.

7.2 Overview of the literature

The literature on strategic environmental policy in models with international trade is mostly based on three seminal articles by Brander and Spencer (Brander and Spencer 1983, Spencer and Brander 1983, and Brander and Spencer 1985) on international duopoly with investment in R&D and government policy in the form of R&D subsidies or an export subsidy. In all the models there are two firms, each in a different country, who are competitors, but do not necessarily produce a homogeneous good. In the basic model (Brander and Spencer 1983) the firms can invest in R&D, which leads to lower marginal production costs and thereby to higher output. As Brander and Spencer show, firms will invest more in R&D when they can do so before they decide on the level of output than when R&D and output are set simultaneously. This is because R&D leads to an outward shift in the firm's reaction curve, forcing the rival's output down. Since both firms behave in the same way, they are caught in a Prisoners' Dilemma; profits would be higher if both firms would reduce their output, but both firms have an individual incentive to increase their own output. National governments have an incentive to provide subsidies for R&D (Spencer and Brander 1983) and export subsidies (Brander and Spencer 1985), pushing their firm's output even further up.

The first use of these models in the field of international environmental problems was to analyze the strategic choice of level of environmental policy. Some examples are Barrett (1994), Ulph (1994, 1996a,b, 1999, 2000), Conrad (1994, 1996ab) and Rauscher (1997). As Brander and Spencer already noted, strategic considerations lead a government to stimulate its firm's production, which in this case happens through a more lenient environmental policy. However, as Barrett (1994), Ulph (1996c), Conrad (1996a) and Rauscher (1997) have pointed out, the behavior of the government is dependent on market conduct. The above mentioned conclusion only holds when firms compete with quantities (Cournot competition). When firms engage in price, or Bertrand, competition governments will want to impose overly strict environmental policies. This was already pointed out by Eaton and Grossman (1986) in the context of Brander and Spencer's original model.

A second use of the models by Brander and Spencer is in the modelling of instrument choice when there is international trade. Ulph (1992) uses a duopoly model where the two firms are located in different countries. The governments want to limit emissions from their firm to a certain level and can choose between taxes and emission ceilings as their policy instrument. Production costs depend on two inputs: one denoted as energy, which is an input that causes pollution, the other is a non-polluting production factor which is referred to as capital. Ulph then considers three cases: a single-stage Cournot model, a two-stage Stackelberg model and a two-stage Cournot model. In the one-stage Cournot model, the firms, knowing which instrument the governments have chosen, set their capital level and output simultaneously. The conclusion from this model is that in a one-shot Cournot model, countries are indifferent between ceilings and taxes. The reason for this is that in a one-shot game there is no strategic interaction and all instruments discussed give the same output. The choice of instrument is then a purely domestic decision.

In the two other cases, firms can invest strategically in capital, thereby changing their production capacity. The driving force behind the results that follow is that firms will invest more in capital when they are regulated through taxes than when they are facing emission ceilings. The reason for this is that the reaction function of a firm is steeper when a tax is imposed than when a ceiling is imposed on the firm. This implies that a firm will react with a larger output change to a given change in foreign output under taxes than under ceilings. The second case discussed by Ulph (1992) is a Stackelberg model where one country acts as a leader and the other as a follower. The outcome is that the Stackelberg follower will prefer ceilings, while the leader is indifferent between taxes and ceilings. This outcome ensures the lowest total output and thereby the highest industry profits.

The third case given by Ulph is the two-stage Cournot model. In this model, firms first simultaneously choose their level of capital, and thereafter simultaneously choose their level of output and energy. In this case, the use of ceilings by both countries is the unique Nash equilibrium in the choice of instruments as long as the share of the two countries' consumption in world consumption is small enough. The reason for this is that under taxes the firms overinvest in capital and thereby increase production. This increases revenues, but also costs. Ulph argues, but does not formally show, that since the firms overexpand output and do not minimize costs at the chosen output level, total firm profits will decrease, even if the other firm uses ceilings. Each country then has an incentive to shift to ceilings, which lowers the incentive to overinvest. The model used by Ulph does not contain any specification for consumers' surplus, but in general the conclusions will hold as long as the consumption of the good in the two countries only represents a small share of world consumption.

In a more recent paper, Ulph (1996b) generalizes the Cournot model described above. Instead of using only two inputs, energy and capital, a more general specification of the cost function is given. Furthermore, Ulph

(1996b) allows for both production and consumption in the two countries. The more general model of technology makes that the use of emission ceilings is no longer always the dominant strategy.

Also in Ulph (1996a) the use of ceilings induces less strategic behavior by the firms than does the use of taxes. However, it is now not always optimal to use ceilings, because there are also consumers living in the two producer countries. With a relatively large producer surplus government prefers ceilings, while with a relative large consumer surplus it prefers taxes.

Feenstra et al. (1996) and Feenstra (1998, Ch.2) extend the model of Ulph (1992) to a fully dynamic analysis. In doing so they use a differential game approach where firms use open-loop investment strategies and feedback strategies for the choice of the polluting input. Their model confirms the conclusions of Ulph (1992) that investment is lower when both countries use ceilings. Furthermore, the situation in which both countries choose ceilings is the unique Nash equilibrium with Feenstra et al. (1996) as well.

A further development is given in Feenstra (1998, Ch.3) where both investments and level of the polluting input are determined by feedback strategies. Now it is not always true that investment is larger under taxes than under ceilings. In the feedback model the substitutability of production factors is important: if the substitution effects are large enough, investment is larger under ceilings than under taxes, and hence governments will prefer taxes.

Both Feenstra et al. (1996) and Feenstra (1998, Ch. 2,3) assume that the product is not consumed in the countries where it is produced. As with Ulph (1992), the results of both models will hold as long as consumption in the two countries only represents a small part of world consumption. However, if consumption is large, governments might prefer taxes to ceilings.

The model used in the remainder of this chapter is a two-stage game where governments first set the instrument, whereafter firms decide on their output level. Thus there is no strategic investment in the model. This resembles the first case in Ulph (1992). However, the instruments that I analyze are different from those in Ulph. We focus on relative standards (or performance standards) complemented with credit trading and on tradable permits. Although the impact of tradable permits resemble those of well calibrated taxes, relative standards differ from the firm emission ceilings analyzed by Ulph. Next to that, we discuss the impact of going from domestically applied instruments to participation in an international emissions trading scheme. We also discuss the incentives for participating in an international emissions trading scheme or sticking to national instruments.

7.3 The Model

There are two producers of a homogeneous good each located in a different country. These producers are the sole producers of the good in the world. Revenues for each producer are represented by $R^i(q_i, q_j)$, where q_i is the output of firm i. The revenue function has the following properties:

$$R^i_i > 0, \qquad R^i_j < 0, \qquad R^i_{ii} < R^i_{ij} < 0 \tag{7.1}$$

where subscripts denote derivatives. Costs for each producer are represented by $C^i(q_i, E_i)$, where E_i is emissions of a pollutant. It is assumed that:

$$C^i_q > 0, \qquad C^i_E < 0, \qquad C^i_{qq} > 0, \qquad C^i_{EE} > 0, \qquad C^i_{qE} < 0 \tag{7.2}$$

The governments of both countries have committed themselves to a certain emission level for their firm that is lower than the business-as-usual level. This assumption makes it possible to focus on the choice of policy instrument without interference from a possible strategic choice of emission level. We limit the choice of instruments at the national level to relative standards and emission ceilings because these two instruments can form the basis for emissions trading. However, it can easily be shown that within this model taxes and tradable permits lead to the same production level as emission ceilings and the analysis for the latter is basically the same as for these other instruments.

In the model, it is assumed that the firms and countries have no market power in the emissions quota market. The rationale for this is that the international emission quota market is likely to be large and firms from several industries will be engaged in emissions trading. Therefore, it is less likely for a firm to have market power in the emission quota market than in the product market.

There are three stages in the game. In the first stage, governments choose between relative standards, emission ceilings, permit trading and credit trading. In the second stage, governments set their instruments such that the overall emission goal $\bar{E}_i$ is realized. With emission ceilings and permit trading, the government simply distributes $\bar{E}_i$ to the firm. In case government i has chosen relative standards or credit trading, it sets the standard $\bar{e}_i$ such that its firm emits $\bar{E}_i$ (before buying or selling permits internationally) in the equilibrium of stage 3. In the third stage, firms choose their output and emission levels.

In the following, we will first analyze instrument choice by the government when international emissions trading is not allowed. After that, we discuss the case where international emissions trading is possible. In both cases, backward induction requires that we first analyze firm behavior and then government behavior.

7.3.1 No International Emissions Trading

We begin by analyzing the case where the two countries do not allow their firms to trade emissions internationally. This means that only domestic instruments are relevant for the model. Since the ultimate goal of this paper is to analyze the preference for international emissions trading scheme, only emission ceilings and relative standards are discussed, since these can form the basis for emissions trading. In the following, we will first analyze the second stage in which the firms set their production level. After that, the choice of instrument by the government is discussed.

Stage Three: Firm Behavior

The government can choose between two instruments of environmental policy: emission ceilings and relative standards. With emission ceilings, a cap equal to $\bar{E}_i$ is placed on the emissions of the firm. Under relative standards, a standard equal to $\bar{e}_i$ is placed on emissions per unit of output. Total allowed emissions with this instrument are then given by $\bar{e}_i q_i$, i.e., the relative standard times output.

In the following, each firm takes the output of the other firm as given when deciding on its own output level. That is, the firms are engaged in Cournot competition.

Emission ceilings. Given the ceiling $\bar{E}_i$ set by the government, the firm's objective function becomes:

$$\begin{aligned} &\max_{q_i, E_i} \quad \Pi^i = R^i(q_i, q_j) - C^i(q_i, E_i) \\ &s.t. \quad\quad E_i \leq \bar{E}_i \end{aligned} \tag{7.3}$$

The first order conditions are

$$R_i^i = C_q^i \tag{7.4}$$

$$-C_E^i = \lambda_i$$

Here, λ_i is the shadow price of emissions. The first order conditions are the usual ones, showing that the firms sets marginal revenue equal to marginal production costs and equates marginal abatement costs with the shadow price of emissions.

Relative Standards. Under a relative standard, the government sets an emission ceiling $\bar{e}_i$ per unit of production. The firm is then allowed to emit $\bar{e}_i q_i$ in total. Since the government is perfectly informed, it sets the relative standard equal to $\frac{\bar{E}_i}{q_i}$. The optimization problem of the firm becomes

$$\begin{aligned} &\max_{q_i, E_i} \quad \Pi^i = R^i(q_i, q_j) - C^i(q_i, E_i) \\ &s.t. \quad\quad E_i \leq \bar{e}_i q_i \end{aligned} \tag{7.5}$$

The first order conditions are

$$R_i^i = C_q^i - \lambda_i \bar{e}_i$$

$$-C_E^i = \lambda_i$$

where λ_i is the shadow price of emissions. Combining the first order conditions gives

$$R_i^i = C_q^i + C_E^i \bar{e}_i \tag{7.6}$$

Comparing (7.4) with (7.6), it is clear that (7.6) contains the additional term $C_{E_i}^i \bar{e}_i$. This term is negative, implying that under relative standards $P < C_q^i$ and that production is larger under relative standards than under emission ceilings (see also Helfand 1991, Ebert 1998 and Dijkstra 1999). The additional term can be seen as an output subsidy (see Gielen et al. (2002) and Fischer 2001)). With relative standards, a firm is rewarded for additional output by additional allowed total emissions. Marginal abatement costs however are larger with relative standards than with emission ceilings when total emissions are the same under the two schemes. To see this, note that output is larger with relative standards, while emissions are the same and $C_{Eq}^i < 0$.

Stages One and Two: Government Choice of Instrument

As mentioned above, it is assumed that the governments involved have signed an international agreement committing them to keep emissions from their firm below a certain threshold. Hence, total and country emissions are fixed. When there is both consumption and production of the good in the domestic country, the welfare function becomes

$$W^h(q_h, q_f) = \mu_h \int_0^y P(Q)dQ - P(y)\mu_h y + R^h(q_h, q_f) - C(q_h, E_h)$$

where h stands for home country, f for the foreign country, $y = q_h + q_f$ is total production and μ_h is the proportion of identical consumers living in country h. The first two terms in the welfare equation give the consumers' surplus, while the last two terms give the producer's surplus.

The first order condition for welfare maximization is

$$\frac{dW^h}{dq_h} = \left(R_h^h - C_q^h\right) + R_f^h \frac{dq_f}{dq_h} - \mu_h y P'(y) \left(1 + \frac{dq_f}{dq_h}\right) = 0 \tag{7.7}$$

The first term gives the difference between marginal revenue and costs of production. Under emission ceilings, this term is zero (from (7.4)), while under relative standards this term is negative (from (7.6)). The second term gives the increase in revenue as a result of the decrease in foreign output. This term is positive. The last term gives the total effect of an increase in domestic production on the consumers' surplus. The effect is positive, and hence indicates that production should be higher when there is domestic consumption.

The term dq_f/dq_h gives the slope of the reaction function of the foreign country. It gives the change in foreign output as a result of a change in domestic output. The sign and size of this term can be derived from the first order condition for profit maximization and differs between instruments.

For emission ceilings, the slope of the reaction function is given by implicitly differentiating equation (7.4) for country f with respect to q_h

$$\frac{dq_f}{dq_h} = \frac{-R_{fh}^f}{R_{ff}^f - C_{qq}^f}, \quad \text{with} \quad -1 < \frac{dq_f}{dq_h} < 0 \tag{7.8}$$

That $-1 < \frac{dq_f}{dq_h} < 0$ follows from (7.1) and (7.2). This ensures that the Nash equilibrium will be stable.

With relative standards, the government will alter the standard when the domestic firm changes its output level. This has an effect on the slope of the reaction function. This can now be found by by implicit differentiation of (7.6) for country f while holding E constant and realizing that $\bar{e} = \bar{E}/q$

$$\frac{dq_f}{dq_h} = \frac{-R_{fh}^f}{R_{ff}^f - C_{qq}^f - \frac{\bar{E}_f}{q_f} C_{qE}^f + \frac{\bar{E}}{q_f^2} C_E^f}, \quad \text{with} \quad -1 < \frac{dq_f}{dq_h} < 0 \tag{7.9}$$

That $-1 < dq_f/dq_h < 0$ follows from (7.43). In Appendix B, we show that at the point of intersection:

$$|dq_f/dq_h|^{rs} > |dq_f/dq_h|^{ec} \tag{7.10}$$

where the superscripts rs and ec stand for relative standards and emission ceilings respectively. In the following, we assume that (7.10) holds everywhere. Equation (7.10) says that a foreign firm regulated through relative standards is more responsive to a change in output by the home firm than a firm regulated through emission ceilings. Suppose the domestic firm decreases production, so that the foreign firm wants to increase production. With relative standards, the firm receives an implicit subsidy on output leading to a larger response to a change in output by the other firm.

A comparison of (7.7) with (7.4) shows that the government will want to increase production above the level attained with emission ceilings. Define

$$V_i^I \equiv R_j^i \frac{dq_j}{dq_i} - \mu_i y P'(y) \left(1 + \frac{dq_j}{dq_i}\right) > 0 \tag{7.11}$$

with $I = ec, rs$ for emission ceilings and relative standards respectively. For the choice of instrument we then find

Proposition 28 *Country i will prefer relative standards to emission ceilings when $-C_E^i \bar{e}^i$ is close enough to V_i^{rs}. Otherwise, the country will prefer emission ceilings.*

Proof From (7.6) and (7.7), it is clear than when $-C_E^i \bar{e}^i = V_i^{rs}$ the optimum is achieved with relative standards. The country will also prefer relative standards to emission ceilings for values of $-C_E^i \bar{e}^i$ close enough to V_i^{rs} since $V_i^{ec} > 0$ and hence, emission ceilings do not attain the optimum. $\square$

Note that the government wants to increase home production, no matter whether the foreign country uses emission ceilings or relative standards. However, since dq_f/dq_h is larger in absolute terms under relative standards than under emission ceilings, the home country will want to increase output more when the foreign country uses relative standards. In that case, the home country is more likely to use relative standards as well.

One of the problems with relative standards is that they can increase production by too much. This is more likely to be the case with intermediate environmental policy, i.e., with environmental policy that is neither very lax nor very stringent. If environmental policy is so lax that it is not binding, then $C_E = 0$. If environmental policy is so strict that it prohibits pollution, $\bar{e} = 0$. In both cases, $C_E\bar{e} = 0$ and there is no difference between absolute and relative standards. However, as policy becomes more strict from a non-binding level onward, $-C_E\bar{e}$ increases to a maximum, to return to zero again as $\bar{e}$ becomes zero. Hence, for intermediate levels of environmental policy, it may happen that relative standards stimulate output by so much that welfare with relative standards is lower than with emission ceilings. The government is then more likely to prefer relative standards when policy is either rather lax (but binding) or rather stringent.

We can be a bit more specific on how much more production the government wants. First of all, note that when there is no domestic consumption, (7.7) becomes

$$\frac{dW^h}{dq_h} = R_h^h + R_f^h \frac{dq_f}{dq_h} - C_q^h = 0 \tag{7.12}$$

This is identical to the first order condition for profit maximization for a Stackelberg leader. A comparison with (7.7) then shows that when the country consumes the good, the optimum production level is higher than the Stackelberg leader production level. Furthermore, we can rewrite revenue for a firm as $R^i(q_h, q_f) = P(q_h, q_f)q_i$. Using this, (7.7) can be written as

$$\frac{dW^h}{dq_h} = (P - C_q^h) + P'(y)\left(1 + \frac{dq_f}{dq_h}\right)(q_h - \mu_h y) = 0 \tag{7.13}$$

The first order condition for welfare optimization is for the first term to equal zero if the firm and the country have no influence on the product price ($P'(y) = 0$) or in the case of autarky ($q_h = \mu_h y$). In those cases, the country will prefer the output level reached by perfect competition in the market, combined with emission ceilings. The second term gives the effect of a change in production on revenue times the trade balance in the product. Hence, to determine the optimal production level, it is important to know whether the country imports or exports the product.

When the country imports the product, $q_h < \mu_h y$, and the last term in (7.13) becomes positive. To optimize welfare, the country should increase production beyond the perfectly competitive level. When the country exports the product, $q_h > \mu_h y$, and the country should have a lower production level than the one realized with perfect competition. Hence, when the country consumes the good, the optimum production level is higher than the Stackelberg leader production level. Depending on whether the country imports or exports the good, optimum production is higher or lower than the full competitive output level respectively.

If countries are identical, we can establish the choice of instrument in equilibrium:

Proposition 29 *If the two countries are identical, there are two Nash equilibria given by (rs_h, rs_f) and (ec_h, ec_f). That is, either both countries use relative standards, or both use emission ceilings.*

Proof It is immediately clear from (7.7) that (rs_h, rs_f) and (ec_h, ec_f) are Nash equilibria for identical countries. First, if $-C_E^i \bar{e}^i = V_i^{rs}$ with relative standards for both countries, then both countries maximize their individual welfare, so that (rs_h, rs_f) constitutes a possible Nash equilibrium. Furthermore, as long as $-C_E^i \bar{e}^i$ is close enough to V_i^{rs} relative standards are the optimal choice for each country. Then suppose that the foreign country chooses emission ceilings. From (7.8), (7.9), using (7.43) it then follows that dq_f/dq_h decreases. There are now two possibilities. First, it may now be that $-C_E^h \bar{e}$ is too large, so that the home country switches to emission ceilings. Note that now dq_h/dq_f also decreases, so that a shift back to relative standards cannot be optimal for the foreign country. Hence, (ec_h, ec_f) is a possible Nash equilibrium. The second possibility is that even though the foreign country switches to emission ceilings, the optimal choice for the home country is still relative standards. But, since the countries are identical, this must mean that relative standards are now optimal for the foreign country too. Hence (rs_h, rs_f) and (ec_h, ec_f) are the only possible Nash equilibria when the countries are identical. □

7.3.2 International Emissions Trading

We now turn to the case where the domestic firm is allowed to trade emissions on the international emission quota market. Again, we will first analyze firm behavior and thereafter government choice of instrument. We will also determine whether allowing international emissions trading leads to higher or lower welfare for the country.

Stage Three: Firm Behavior

In this part, the behavior of the firms is analyzed when international emissions trading is allowed. There are basically two forms of emissions trading, each based on one of the instruments discussed above. Emissions trading based on emissions ceilings will be denoted as permit trading, while emissions trading based on relative standards will be denoted as credit trading. In the following, it is assumed that there is an international emissions trading market on which neither the firms, nor their governments have market power. This implies that firms and governments take the emission quota price as given.

Permit Trading. Taking the initial distribution of permits, $\bar{E}_i$ and the price of permits, T as given, the firm's objective becomes:

$$\max_{q_i, E_i} \Pi_i = R^i(q_i, q_j) - C^i(q_i, E_i) - T(E_i - \bar{E}_i) \tag{7.14}$$

The first order conditions are:

$$R^i_i = C^i_q \tag{7.15}$$

$$-C^i_E = T \tag{7.16}$$

The first order conditions are basically the same as those for an emission ceiling, with T replacing λ_i. However, different from emission ceilings, firm emissions can now change with a change in output.

Credit Trading. With credit trading, firms are regulated through relative standards, and are then allowed to sell credits if they can stay below the standard. The objective function of the firm regulated in this way becomes

$$\underset{q_i,E_i}{max}\ \Pi_i = R^i(q_i,q_j) - C^i(q_i,E_i) - T(E_i - \bar{e}_i q_i)$$

The first order conditions are

$$R_i^i + T\bar{e}_i = C_q^i \tag{7.17}$$

$$-C_E^i = T \tag{7.18}$$

Combining the two first order conditions gives

$$R_i^i = C_q^i + C_E^i \bar{e}_i \tag{7.19}$$

This is identical to (7.6), the same condition for relative standards.

Stages One and Two: Government Policy

With international emissions trading, the government has two choices to make. First of all, which domestic instrument to choose and secondly, whether or not to allow international emissions trading. In this section, these issues are dealt with. Furthermore, we show how a shift to international emissions trading affects firm profits.

In the analysis below, we need to know the sign and relative size of the slope of the reaction function, given by dq_i/dq_j, of the country under different instruments. When the country uses permit trading, the slope of the reaction function can be derived from the total differentiation of (7.15) and (7.16)

$$\frac{dq_i}{dq_j} = \frac{R_{ij}^i C_{EE}^i}{\Pi_{ii}^i(pt)}, \quad -1 < \frac{dq_i}{dq_j} < 0 \tag{7.20}$$

The fact that $-1 < \frac{dq_i}{dq_j} < 0$ follows from (7.1), (7.2) and (7.32) given in Appendix A.

With credit trading, the government will adjust the relative standard when the firm changes its output level. The reason is that the government wants to commit to the domestic emission target given. The relative standard is therefore given by $\bar{E}_i/q_i$. Suppose that the firm buys emission quotas internationally and that the government does not adjust the standard. Because the firm now can emit more, it will also produce more. If the government did not adjust the relative standard, the firm would be allowed increase emissions by even more than the amount it had bought on the international market. So in deriving the slope of the reaction function under credit trading, we have to take into account that the government will adjust the relative standard when the firm changes output. The slope of the reaction function under credit trading can then be derived from total differentiation of (7.17) and (7.18)

$$\frac{dq_i}{dq_j} = \frac{R^i_{ij} C^i_{EE}}{\Pi^i_{ii}(ct; \bar{E})}, \quad -1 < \frac{dq_i}{dq_j} < 0 \tag{7.21}$$

The fact that $-1 < \frac{dq_i}{dq_j} < 0$ follows from (7.1), (7.2) and (7.37) given in Appendix A. In Appendix B we show that at the point of intersection, the slope of the reaction function under credit trading is less steep than under permit trading. That is,

$$\left|\frac{dq_i}{dq_j}\right|^{ct} < \left|\frac{dq_i}{dq_j}\right|^{pt} \tag{7.22}$$

We will assume that this inequality holds throughout. This result is the reverse of what we found under domestic instruments. The reason for this result is as follows. When a firm increases its output, it will buy emission quotas on the international market at the fixed price T. However, under credit trading, the government will react to an increase in production by tightening the relative standard, thereby putting an implicit tax on the purchase of credits. This implies that the cost of buying emission quotas in the market is higher under credit trading than under permit trading.

Comparing the slopes of the reaction functions of all instruments (see Appendix B) gives that at the respective points of intersection:

$$\left|\frac{dq_i}{dq_j}\right|^{pt} > \left|\frac{dq_i}{dq_j}\right|^{ct} > \left|\frac{dq_i}{dq_j}\right|^{rs} > \left|\frac{dq_i}{dq_j}\right|^{ec} \tag{7.23}$$

We will assume that these inequalities hold throughout. Equation (7.23) shows that with international permit trading, a country will adjust its output more as a reaction to an output change by the foreign firm than under absolute standards. The reason for this is that the firm can now trade permits on the international emissions market. This implies that when it wants to increase production, it can keep marginal production costs lower by buying permits. On the other hand, when it wants to decrease output, it can sell permit on the market, giving an additional incentive to decrease production. For the same reason, it holds that $|dq_i/dq_j|^{ct} > |dq_i/dq_j|^{rs}$.

The next issue to be addressed is how the shift to international emissions trading affects firm profits. To do so, we will make use of the mean value theorem (see Sydsæter and Hammond 1995, p. 222 and Brander and Spencer 1983). In particular, let $f(x)$ be continuous and differentiable in the interval (a, b). Then there exists an interior point α in (a, b) such that

$$\Delta f \equiv f(b) - f(a) = f'(\alpha)(b - a)$$

where $f'(\alpha)$ is the differential of f evaluated at α with $\alpha = a + \beta(b - a)$ for some $\beta \in (0, 1)$.

Using the mean value theorem the effect of the shift to international emissions trading can in general be given as

$$\Delta\Pi^i = \frac{d\Pi^i}{d\lambda_i}(T - \lambda_i^{nt}) = \left[\frac{\partial\Pi^i}{\partial q_i}\frac{dq_i}{d\lambda_i} + \frac{\partial\Pi^i}{\partial q_j}\frac{dq_j}{dq_i}\frac{dq_i}{d\lambda_i} + \frac{\partial\Pi^i}{\partial E_i}\frac{dE_i}{d\lambda_i} + \frac{\partial\Pi^i}{\partial\lambda_i}\right](T - \lambda_i^{nt}) \tag{7.24}$$

where λ_i^{nt} gives the shadow price of emissions with domestic regulation and λ_i lies somewhere between λ_i^{nt} and T. With either instrument, the firm sets $\partial\Pi^i/\partial q_i = \partial\Pi^i/\partial E_i = 0$, so that with permit trading (7.24) can be written as

$$\Delta\Pi^i = \left[R^i_j \frac{dq_j}{dq_i}\frac{dq_i}{d\lambda_i} - (E_i - \bar{E}_i)\right]\left(T - \lambda_i^{nt}\right) \tag{7.25}$$

and with credit trading as

$$\Delta\Pi^i = \left[R^i_j \frac{dq_j}{dq_i}\frac{dq_i}{d\lambda_i} - (E_i - \bar{e}_i q_i)\right]\left(T - \lambda_i^{nt}\right) \tag{7.26}$$

In both cases, the first term within square brackets gives the change in revenue because of the change in foreign production. This change is caused by the change in domestic production from the shift to international emissions trading. This effect only reflects the shift to international emissions trading by the home country, while the foreign country is assumed not to change its policy, with foreign policy either being domestic regulation or international emissions trading. It is shown in Appendix C that $dq_i/d\lambda_i$ is negative for all cases, so that the first term in both (7.25) and (7.26) has a negative sign. The second term reflects the proceeds from emissions trading. This term is positive when the firm is a buyer of emission quotas and negative when it is a seller of quotas.

We can then see how the shift to emissions trading affects profits of the firms.

Proposition 30 *Firm profits will always increase with a shift to international emissions trading when the firm becomes a buyer of emission quotas. When the firm becomes a seller of quotas, profits will increase from the shift to emissions trading if and only if* $\left(\bar{E}_i - E_i\right) > -R^i_j \frac{dq_j}{dq_i}\frac{dq_i}{d\lambda_i}$.

Proof: First of all, the term $R^i_j \frac{dq_j}{dq_i}\frac{dq_i}{d\lambda_i}$ is negative. Furthermore, $(E_i - \bar{E}_i)$ is positive (negative) when the firm is a buyer (seller) of emissions quotas, which will be the case when $T < \lambda_i^{nt}$ ($T > \lambda_i^{nt}$). It then follows that (7.25) and (7.26) are always positive when $T < \lambda_i^{nt}$ and are only positive for $T > \lambda_i^{nt}$ when $-R^i_j \frac{\partial q_j}{\partial q_i}\frac{\partial q_i}{\partial \lambda_i} < (\bar{E}_i - E_i)$. $\square$

Proposition 30 implies that a firm's profits may decrease as a result of a shift to international emissions trading. This will happen when the firm becomes a seller of emission quotas and the negative effect on the firm's revenue in the goods market is larger than the positive revenue from emissions trading. In this case, the firm may resist the transition to international emissions trading.

W now turn to the optimal instrument choice by the government. Welfare of the home country, with domestic consumption and international emissions trading, is given by

$$W^h = \mu_h \int_0^y P(y)dy - P(y)\mu_h y + R^h(q_h, q_f) - C(q_h, E_h) - T\left(E_h - \bar{E}_h\right) \tag{7.27}$$

Differentiating with respect to q_h yields

$$\frac{dW^h}{dq_h} = R_h^h - C_q^h + R_f^h \frac{dq_f}{dq_h} - \mu_h y P'(y)\left(1 + \frac{dq_f}{dq_h}\right) = 0 \tag{7.28}$$

Equation (7.28) is identical to the first order condition for welfare maximization without international emissions trading. The implication is that the optimization problem of the government is basically the same in the two cases. However, there is a difference in that international emissions trading changes the price of emissions and thereby the actual emission level of the country. This in turn will affect welfare, and the effect may be different for different instruments. The first order condition for welfare maximization does show that permit trading always leads to too little output. Credit trading may then improve welfare as it leads to higher output. Output under credit trading may however be too large so that permit trading would be preferable.

Proposition 31 *Suppose a country engages in international emissions trading. Then the country will prefer credit trading to permit trading when $T\bar{e}_i$ is close enough to V_i^{ct}. Otherwise, the country will prefer permit trading.*

Proof The proposition is similar to Proposition 28 and so is the proof, which is therefore omitted. □

With international emissions trading we can show the following for the possible Nash equilibria

Proposition 32 *Given that the two countries are identical, that both engage in international emissions trading and that μ_i is small, the possible Nash equilibria in instrument choice are given by (pt_h, pt_f), (ct_h, ct_f), (pt_h, ct_f), and (ct_h, pt_f).*

Proof Suppose that both countries have adopted permit trading and that the initial limit on emissions is such that both countries are indifferent between permit and credit trading, given that the other country chooses permit trading. Then suppose that f chooses credit trading. By assumption, this does not affect f's welfare. However, for country h, (7.28) changes. Specifically, the term $R_f^h \frac{dq_f}{dq_h}$ decreases since $\left|\frac{dq_i}{dq_j}\right|^{pt} > \left|\frac{dq_i}{dq_j}\right|^{ct}$ from (7.22). This implies that h now wants to increase output by *less* than it did when country f used permit trading. However, given the choice of international emissions trading, the instrument that gives least production is permit trading, and so h will stick to permit trading. This shows that (pt_h, ct_f) is a Nash equilibrium. Since countries are identical, a similar reasoning shows that (ct_h, pt_f) is a Nash equilibrium. Furthermore, it is clear that (pt_h, pt_f) is a Nash equilibrium for $T\bar{e}^i$ much smaller, or much larger than V_i^{ct} and that (ct_h, ct_f) is an Nash equilibria for $T\bar{e}^i$ close enough to V_i^{ct}. □

We see that, whereas with domestic instruments identical countries always choose identical instruments, with international emissions trading, identical countries may choose different instruments. The reason for this is as follows. With domestic instruments, a shift by the foreign country from emission ceilings to relative standards increases the incentive for the home country to increase its production. When it uses relative standards, the foreign country will reduce its production more as a response to a domestic increase in output than it would do with emission ceilings. Hence, it pays more for the domestic country to shift from emission ceilings to relative standards. However under international emissions trading, a shift by the foreign country to credit trading makes its firm's reaction function more elastic (see equation (7.23)). This reduces the domestic country's incentive to increase its production. Hence, it will be reinforced in its choice of permit trading. This result will only hold when μ_h is small. If μ_h is large, the consumers' surplus is more important than the producers' surplus, and hence the country will prefer higher total output. In that case, a shift to credit trading by the foreign country will increase the incentive for the domestic country to make a similar shift since now, its own increase in output will not be outdone by a large decrease in output in the foreign country.

Using the mean value theorem the effect of a change in welfare as a result from the shift to international emissions trading can expressed as follows

$$\Delta W^h = \frac{dW^h}{d\lambda_h}\left(T - \lambda_h^{nt}\right) \tag{7.29}$$

In (7.29), $dW^h/d\lambda_h$ is evaluated at a value of λ between λ_h^{nt} and T, where

$$W^h = \mu_h \int_0^y P(y)dy - P(y)\mu_h y + R^h(q_h, q_f) - C(q_h, E_h) - \lambda_h\left(E_h - \bar{E}_h\right)$$

Writing out $dW^h/d\lambda_h$ and noting that the firm always sets $-C_E^h = \lambda_h$, (7.29) becomes

$$\begin{aligned}\Delta W^h = \Bigg[&\frac{dq_h}{d\lambda_h}\left(R_h^h - C_q^h\right) + R_f^h \frac{dq_f}{dq_h}\frac{dq_h}{d\lambda_h} + (\bar{E}_h - E_h) \\ &- \mu_h y P'(y)\frac{dq_h}{d\lambda_h}\left(1 + \frac{dq_f}{dq_h}\right)\Bigg]\left(T - \lambda_h^{nt}\right)\end{aligned} \tag{7.30}$$

The first term in square brackets gives the difference between marginal revenue and marginal cost. The sign of this term depends on whether the country uses credit or permit trading. In the first case $R_{q_h}^h < C_{q_h}^h$ and the term becomes positive, while with permit trading the term vanishes as can be seen from (7.15). The second term in square brackets reflects the reaction by the foreign country to a domestic change in production. This term is negative. The third term in the square brackets reflects the volume of trade and is positive when the country exports emission quotas and negative when it imports them. Finally, the fourth term within square brackets gives the overall change in price times the amount consumed in the home country and is thereby an indicator of consumer welfare. This term is positive.

In the following we will analyze for both instruments separately whether a shift to international emissions trading leads to an increase in welfare or not. With both instruments, there are two cases to consider since the country can become an importer or an exporter of emission quotas.

Permit Trading. With permit trading, the first term in (7.30) vanishes since $R^h_{q_h} = C^h_{q_h}$ from (7.15) When $T > \lambda^{ec}_h$, the country becomes a seller of permits and $(\bar{E}_h - E_h)$ becomes positive. This results in lower domestic production, higher foreign production, and lower total production. It follows that firm profits from production and the consumers' surplus decrease. We can then see from (7.30) that the shift to international emissions trading will only increase welfare when the direct gain from emissions trading is larger than the combined loss in firm profits and consumers' surplus.

When $T < \lambda^{ec}_h$ the country becomes a buyer of emission quotas and $(\bar{E}_h - E_h)$ becomes negative. It is then immediately clear from (7.30) that welfare increases in this case. Now, the lower world price of permits leads to an increase in domestic and world production, leading to an increase in both domestic firm profits and consumers surplus. This implies that when $T < \lambda^{ec}_h$, the country will never use emission ceilings and prefers international emissions trading.

Credit Trading. The only difference with permit trading is that with credit trading, the first term in (7.30) becomes positive from (7.19), showing that there is a production distortion compared to the case with permit trading. We start the analysis with the case where, $T > \lambda^{rs}_h$ and the country becomes an exporter of credits so that $(\bar{E}_h - E_h)$ becomes positive. Again we find that firm profits from production and the consumers' surplus decrease. The arguments are the same as under permit trading, but now the use of credit trading leads to a distortion since marginal revenue is not equal to marginal costs. The higher world price of credits leads to a decrease in production and thereby to a decrease in this distortion. Therefore in this case, this effect leads to a welfare increase. There are now two effects, the direct gain from emissions trading and the reduction in the production distortion, pointing to a welfare increase. However, there are also two factors, the decrease in profits from production and the decrease in consumers' surplus, that point to a welfare decrease. Hence, the total effect is ambiguous.

When $T < \lambda_h^{rs}$, the country becomes an importer of emission quotas and $(\bar{E}_h - E_h)$ becomes negative. This results in an increase in domestic production and a decrease in foreign production, however, total world production will increase and the world price of the product will decrease. Three factors now point to an increase in welfare, while one points to a decrease. The decrease in welfare comes from a larger distortion of production compared to the optimal as shown by the first term in (7.30). However, foreign production is decreased, the country has lower costs from emissions and consumers gain from lower world prices. Hence, as long as the effect of the production distortion is not too large, allowing international emissions trading leads to an increase in welfare in this case.

We can summarize one of the results in the following proposition

Proposition 33 *Given the instrument of environmental policy, a shift to international emissions trading does not always lead to an increase in welfare.*

In the following, we will analyze which combinations of instruments constitute a Nash equilibrium. It is assumed that there are two identical countries that produce the good and that the producing countries are small consumers of the good (μ is small). We will first analyze the case where $T < \lambda_i^{nt}$ and thereafter the case where $T > \lambda_i^{nt}$.

Case 1: $T < \lambda_i^{nt}$. The analysis above shows that in this case, the country will never choose emission ceilings as its instruments, because a shift to permit trading will always increase welfare. Therefore the instruments the countries will choose between are relative standards and permit and credit trading. Since $T < \lambda_i^{nt}$, we find that $q_i^{ct} > q_i^{pt}, q_i^{rs}$. However, it is not clear whether q_i^{pt} is larger or smaller than q_i^{rs}.

First, suppose that T is such that $q_i^{rs} < q_i^{pt} < q_i^{ct}$. From (7.28) we know that the country prefers a higher output than under permit trading. Thus if $q_i^{pt} > q_i^{rs}$, the countries will never use relative standards and (pt_h, pt_f), (ct_h, ct_f), (pt_h, ct_f), and (ct_h, pt_f) are the only possible Nash equilibria.

Next suppose that T is such that $q_i^{pt} < q_i^{rs} < q_i^{ct}$. In this case, the combinations (pt_h, pt_f), (ct_h, ct_f), and (rs_h, rs_f) are Nash equilibria when these instruments are the optimal choice for both countries. The question is whether it is possible that the countries choose different instruments. Suppose the limit on emissions and the international emissions quota price are such that a country is indifferent between relative standards and credit trading given that the other country chooses relative standards and furthermore suppose that both countries have chosen relative standards. Then let country f shift to credit trading. From (7.23) it is clear that (7.28) now changes so that country h has a larger incentive to increase production. This means that credit trading now has become the optimal choice of instrument for country h. As country h shifts to credit trading, country f now also prefers credit trading to relative standards. In this case, (rs_h, ct_f) and (ct_h, rs_f) are not Nash equilibria.

Now suppose that the limit on emissions in each country and the international emission quota price are such that the countries are indifferent between permit trading and relative standards, given that both choose permit trading and let both countries use permit trading. Then country f shifts to relative standards. This affects (7.28) for country h such that it now wants to increase output less than before, so that it will stick with permit trading. Hence, (pt_h, rs_f) and (rs_h, pt_f) are possible Nash equilibria. Also (pt_h, ct_f), and (ct_h, pt_f) can be Nash equilibria in this case when the gains from international emissions trading are such that the countries always prefer credit trading to permit trading.

So in Case 1, only emission ceilings will never be used. All other instruments, permit trading, credit trading and relative standards, can be used by the two countries and all combinations between any two of these three remaining instruments can constitute Nash equilibria.

Case 2: $T \geq \lambda_i^{nt}$. From Propositions 29 and 32 it is clear that (ct_h, ct_f), and (rs_h, rs_f) are possible Nash equilibria when the gains to international emissions trading are negative and that (pt_h, pt_f), (ct_h, ct_f), (pt_h, ct_f), and (ct_h, pt_f) are possible Nash equilibria when the gains to international emissions trading are always positive. The question then is whether combinations of domestic and international instruments can constitute Nash equilibria.

In this case, $q_i^{pt} < q_i^{ct}, q_i^{ec}, q_i^{rs}$ and $q_i^{ec} < q_i^{rs}$ and also here permit trading and emission ceilings lead to lower than optimal output. However, a switch to relative standards or credit trading may lead to too high output. In this case, it is uncertain whether q_i^{ct} is smaller or larger than q_i^{ec}. First assume that $q_i^{ct} > q_i^{ec}$ so that $q_i^{pt} < q_i^{ec} < q_i^{ct} < q_i^{rs}$. Suppose then that $T = \lambda_i^{rs}$, so that the countries are indifferent between relative standards and credit trading. Furthermore, assume that both countries have chosen relative standards. Then suppose that country f shifts to ct. This alters (7.28) for h such that it now has an even larger incentive to increase output. However, it cannot increase output more than by choosing rs. Hence, (rs_h, ct_f) and (ct_h, rs_f) are possible Nash equilibria. Next suppose that $T > \lambda_i^{rs}$ and that the national limits on emissions are such that the countries are indifferent between emission ceilings and credit trading and that both have chosen emissions ceilings. Let f shift to ct. This changes (7.28) for h, so that it now has a greater incentive to increase output. Country h then no longer chooses ec, but will shift to ct. Hence, (ec_h, ct_f) and (ct_h, ec_f) are not Nash equilibria in this case. Now suppose that $T \geq \lambda_i^{rs}$ and that the national limits on emissions are such that both countries are indifferent between permit trading and emissions ceilings and that both have chosen emission ceilings. Let f shift to pt. This changes (7.28) for h so that it now has an incentive to increase output. Depending how strong this effect is and how much rs and ct increase production, country h may now either stick with ec or shift to rs or ct. If it sticks with ec, we have a new equilibrium. Hence (ec_h, pt_f) and (pt_h, ec_f) are possible Nash equilibria in this case. If h shifts to rs or ct, country f has an incentive to increase output. However, it may be that this incentive is not very large and that f is better off with pt. So also (rs_h, pt_f) and (pt_h, rs_f) are possible Nash equilibria in this case.

Now assume that $q_i^{ct} < q_i^{ec}$ so that $q_i^{pt} < q_i^{ct} < q_i^{ec} < q_i^{rs}$. Again assume that T and the national limits on emissions are such that the countries are indifferent between emission ceilings and credit trading and that both have chosen emissions ceilings. Let f shift to ct. This changes (7.28) for h, so that it now has a greater incentive to increase output. Country h will then have an incentive to increase output even more. It may then be optimal to stick with ec or to shift to rs. In the latter case, country f's incentive to increase output increases, so that it will shift back to ec. However, from Proposition (29) we know that (ec, rs) is not an equilibrium. Hence, in this case, (ec_h, ct_f) and (ct_h, ec_f) are possible Nash equilibria.

Hence, in Case 2, all instruments can be used by the two countries and all possible combinations between any two of the four instruments can be Nash equilibria.

The two cases then show that two identical countries can choose different instruments in a Nash equilibrium. Moreover, we have now shown that it is possible for one country to choose a form of international emissions trading, while the other country chooses not to participate in international emissions trading.

7.4 Conclusions

In this chapter I have presented a model of duopolistic international trade with the two competitors situated in different countries. It is assumed that the country has committed itself to a certain emission target for the industry under analysis. Within this setting, I have analyzed government preferences for instruments of environmental policy and for whether or not the government should let the domestic firm participate in an international emissions trading scheme. At the national level, countries can either choose an emission ceiling or relative standards for their firm. The two instruments have a different impact on the regulated industry, with relative standards leading to higher output and higher marginal abatement costs. If the country allows international emissions trading, the two instruments are transformed to permit and credit trading respectively, with credit trading leading to higher output and marginal abatement costs than permit trading.

The analysis leads to two main conclusions. With imperfect competition, governments have an incentive to increase production, which is strengthened further when there is domestic consumption. The reason is that increasing output of the domestic firm leads to higher profits because the foreign firm will decrease its output. If there is domestic consumption, there is an additional gain since total production will increase with an increase in domestic output, so that domestic consumer surplus will increase.

Since relative standards and credit trading lead to higher production levels than other instruments, countries may prefer these instruments. More precisely, as long as these two instruments do not lead to too large an increase in production, governments will prefer them over emission ceilings and permit trading respectively. If both governments then choose relative standards or credit trading, firm profits will actually decrease, since now both firms increase production. However, as long as domestic consumption is large enough, this will lead to an increase in domestic welfare.

The second main result is that international emissions trading may not always be welfare improving. This is especially the case when the country becomes a seller of emission quotas. In this case, domestic and global output will decrease and the world price of the product will increase. This leads to lower firm profits and lower consumers' surplus. Although emissions trading per se leads to an increase in profits for the firm, the other effects can be so large as to outweigh this direct profit from emissions trading.

Another result is that with international emissions trading, two identical countries may use different instruments in equilibrium. The choice of instrument by the domestic country affects how its firm will react to a change in production by the foreign country. We find that when one firm increases it output, the other firm will reduce its output most under permit trading and least under emission ceilings. Because of this difference in reaction under different instruments, countries have an incentive to react strategically to the instrument choice of the other country. Here all possible combinations between any two instruments are possible Nash equilibria. However, when both countries become buyers of quotas on the international market they will never choose emission ceilings.

Appendix A: Second order conditions

International Permit Trading With international permit trading, the second order condition for profit maximization by the firm is given by

$$\mathbf{\Pi}_{xx} \equiv \begin{pmatrix} R^i_{ii} - C^i_{qq} & -C^i_{qE} \\ -C^i_{qE} & -C^i_{EE} \end{pmatrix} \text{ is negative semidefinite} \tag{7.31}$$

From this, we can derive several conditions on the cost function. The determinant of (7.31) must be positive and is given by

$$\Pi^i_{ii}(pt) \equiv -R^i_{ii}C_{EE} + C_{qq}C_{EE} - C^2_{qE} \geq 0 \tag{7.32}$$

Furthermore, it must hold that $\mathbf{hC_{xx}h'} \leq 0$ for any vector $\mathbf{h}$. Letting $\mathbf{h} = (q \quad E)$ then gives

$$q^2R^i_{ii} - q^2C_{qq} - 2qEC_{qE} - E^2C_{EE} \leq 0 \tag{7.33}$$

Other conditions needed are

$$qC_{qE} + EC_{EE} < 0 \tag{7.34}$$

$$C_{qq}C_{EE} - C^2_{qE} \geq 0 \tag{7.35}$$

Condition (7.34) ensures that under credit trading marginal revenue decreases with emissions. Condition (7.35) is the determinant of the second order condition for cost minimization. The latter is equal to (7.31) but with the term R^i_{ii} deleted.

International Credit Trading In this case, the government will adjust the relative standard when the firm changes output. The second order condition for profit maximization by the firm is then given by

$$\mathbf{\Pi}_{xx} \equiv \begin{pmatrix} R^i_{ii} - C^i_{qq} - \frac{\bar{E}}{q}C_{qE} + \frac{\bar{E}}{q^2}C_E & -C^i_{qE} - \frac{\bar{E}}{q^2}C_{EE} \\ -C^i_{qE} & -C^i_{EE} \end{pmatrix} \tag{7.36}$$

is negative semidefinite

The determinant of (7.36) must be positive and is given by

$$\Pi^i_{ii}(ct;\bar{E}) \equiv -R^i_{ii}C_{EE} + C_{qq}C_{EE} - \frac{\bar{E}}{q^2}C_E C_{EE} - C^2_{qE} \geq 0 \tag{7.37}$$

Another condition needed is

$$C_{qq}C_{EE} - \frac{\bar{E}}{q^2}C_E C_{EE} - C^2_{qE} \geq 0 \tag{7.38}$$

This condition is the determinant of the second order condition for cost minimization. The latter is equal to (7.36) but with the term R^i_{ii} deleted.

Appendix B: Slopes of the Reaction Functions

The slopes of the reaction function are given by (7.8) for emission ceilings, (7.9) for relative standards, (7.20) for permit trading, and (7.21) for credit trading.

Dividing both numerator and denominator in (7.8) and (7.9) by -1 gives

$$\frac{dq_i^{ec}}{dq_j} = \frac{R^i_{ij}}{-R^i_{ii} + C^i_{qq}} \tag{7.39}$$

$$\frac{dq_i^{rs}}{dq_j} = \frac{R^i_{ij}}{-R^i_{ii} + C^i_{qq} + \frac{\bar{E}_i}{q_i}C^i_{qE} - \frac{\bar{E}}{q_i^2}C^i_E} \tag{7.40}$$

Dividing both numerator and denominator in (7.20) and (7.21) by C_{EE}

gives

$$\frac{dq_i^{pt}}{dq_j} = \frac{R_{ij}^i}{-R_{ii}^i + C_{qq}^i - \frac{{C_{qE}^i}^2}{C_{EE}^i}} \tag{7.41}$$

$$\frac{dq_i^{ct}}{dq_j} = \frac{R_{ij}^i}{-R_{ii}^i + C_{qq}^i - \frac{\bar{E}}{q^2}C_E^i - \frac{{C_{qE}^i}^2}{C_{EE}^i}} \tag{7.42}$$

We will assume that[1]

$$-q_i C_{qE}^i + C_E^i > 0 \tag{7.43}$$

Then it is easily seen that

$$\left|\frac{dq_i}{dq_j}\right|^{pt} > \left|\frac{dq_i}{dq_j}\right|^{ct} \quad \text{and} \quad \left|\frac{dq_i}{dq_j}\right|^{pt} > \left|\frac{dq_i}{dq_j}\right|^{ec}$$

For a comparison of credit trading and relative standards we find from (7.40) and (7.42):

$$\left|\frac{dq_i}{dq_j}\right|^{rs} < \left|\frac{dq_i}{dq_j}\right|^{ct}$$

because by (7.34):

$$\frac{E}{q}C_{qE} > -\frac{C_{qE}^2}{C_{EE}}$$

For a comparison of relative standards and emission ceilings we find from (7.39) and (7.40) that by (7.43):

$$\left|\frac{dq_i}{dq_j}\right|^{ec} < \left|\frac{dq_i}{dq_j}\right|^{rs}$$

Combining our finding shows that

$$\left|\frac{dq_i}{dq_j}\right|^{pt} > \left|\frac{dq_i}{dq_j}\right|^{ct} > \left|\frac{dq_i}{dq_j}\right|^{rs} > \left|\frac{dq_i}{dq_j}\right|^{ec}$$

[1]For example, with a quadratic cost function given by $C(q,E) = aq^2 + b(q-E)^2 + k$ we find that $-q_i C_{qE}^i + C_E^i = 2bE > 0$.

Appendix C: Comparative Statics

In this appendix, we give the effect of a change in the permit price on firm output. These effects depend on both domestic and foreign instrument choice. The comparative statics are found by differentiating the relevant first order conditions with respect to T and inserting the relevant foreign reaction function.

We will assume that own effects of output on marginal profit dominate cross effects. This gives rise to the following condition.

$$\Pi^i_{ii}(I_i)\Pi^j_{jj}(I_j) - \Pi^i_{ij}(I_i)\Pi^j_{ji}(I_j) \geq 0 \tag{7.44}$$

where

$$\Pi^i_{ij}(I_i) = R^i_{ij} > 0 \tag{7.45}$$

for domestic instruments and

$$\Pi^i_{ij}(I_i) = C^i_{EE}R^i_{ij} > 0 \tag{7.46}$$

for international permit and credit trading. Furthermore,

$$\begin{aligned} \Pi^i_{ii}(ec) &= -R^i_{ii} + C^i_{qq} \geq 0 && (7.47) \\ \Pi^i_{ii}(rs) &= -R^i_{ii} + C^i_{qq} + \frac{\bar{E}_i}{q_i}C^i_{qE} - \frac{\bar{E}}{q_i^2}C^i_E \geq 0 && (7.48) \end{aligned}$$

We then find the following. When country i uses international permit trading and country j uses domestic instruments we find by differentiating (7.15) and (7.16) with respect to T and using (7.8) for emission ceiling or (7.9) for relative standards

$$\frac{dq_i}{dT} = \frac{C^i_{qE}\Pi^j_{jj}(I_j)}{\Pi^i_{ii}(pt)\Pi^j_{jj}(I_j) - C_{EE}R^i_{ij}R^j_{ji}} < 0$$

The sign follows from (7.2), (7.32), (7.44), (7.47) and (7.48).

When country i uses international credit trading and country j uses domestic instruments we find by differentiating (7.19) and (7.18) with respect to T and using (7.8) for emission ceiling or (7.9) for relative standards

$$\frac{dq_i}{dT} = \frac{\left(\bar{e}_i\, C^i_{EE} + C^i_{qE}\right)\Pi^j_{jj}(I_j)}{\Pi^i_{ii}(ct)\Pi^j_{jj}(I_j) - C^i_{EE}R^i_{ij}R^j_{ji}} < 0 \tag{7.49}$$

The sign follows from (7.37), (7.34), (7.44), (7.47) and (7.48).

When both countries use permit trading, we find by differentiating (7.15) and (7.16) with respect to T and using (7.20)

$$\frac{dq_i}{dT} = \frac{C^i_{qE}\Pi^j_{jj}(pt) + C^j_{qE}C^i_{EE}R^i_{ij}}{\Pi^i_{ii}(pt)\Pi^j_{jj}(pt) - C^i_{EE}C^j_{EE}R^i_{ij}R^j_{ji}} < 0 \tag{7.50}$$

The sign follows from (7.2), (7.32), (7.35) and (7.44) and holds when the two firms are similar enough.

When both countries use credit trading we find by differentiating (7.19) and (7.18) with respect to T and using (7.21)

$$\frac{dq_i}{dT} = \frac{\left(C^i_{qE} + \bar{e}_i C^i_{EE}\right)\Pi^j_{jj}(ct;\bar{E}) + C^i_{EE}R^i_{ij}\left(C^j_{qE} + \bar{e}_j C^j_{EE}\right)}{\Pi^i_{ii}(ct;\bar{E})\Pi^j_{jj}(ct;\bar{E}) - C^i_{EE}C^j_{EE}R^i_{ij}R^j_{ji}} < 0 \tag{7.51}$$

The sign follows from (7.2), (7.37), (7.38) and (7.44) and holds when the two firms are similar enough.

When country i uses permit trading and country j uses credit trading we find by differentiating (7.15) and (7.16) with respect to T and using (7.21)

$$\frac{dq_i}{dT} = \frac{C^i_{qE}\Pi^j_{jj}(ct;\bar{E}) + C^i_{EE}R^i_{ij}\left(C^j_{qE} + \bar{e}_j C^j_{EE}\right)}{\Pi^i_{ii}(pt)\Pi^j_{jj}(ct;\bar{E}) - C^i_{EE}C^j_{EE}R^i_{ij}R^j_{ji}} < 0 \tag{7.52}$$

The sign follows from (7.2), (7.32), (7.37), (7.38) and (7.44) and holds when the two firms are similar enough.

When country i uses credit trading and country j uses permit trading we find by differentiating (7.19) and (7.18) with respect to T and using (7.20)

$$\frac{dq_i}{dT} = \frac{\left(C^i_{qE} + \bar{e}_i C^i_{EE}\right)\Pi^j_{jj}(pt) + C^i_{EE}R^i_{ij}C^j_{qE}}{\Pi^i_{ii}(ct;\bar{E})\Pi^j_{jj}(pt) - C^i_{EE}C^j_{EE}R^i_{ij}R^j_{ji}} < 0 \tag{7.53}$$

The sign follows from (7.2), (7.32), (7.37), (7.35) and (7.44) and holds when the two firms are similar enough.

Chapter 8

Interest Group Preference for Instruments of Environmental Policy: An Overview

8.1 Introduction

In environmental politics, two things have to be decided: the level of abatement and the method of implementation. Economists have tried to shed light on both issues. The standard economic answer to the first question is: one should abate up to the level where marginal social costs are equal to marginal social benefits. However, this answer is not always of much help, mainly because the marginal benefits are unknown. But economists have also taken up this challenge by trying to measure the value of what was previously immeasurable (see Hanemann 1994).

So far, economists seem to have contributed more to answering the second question. Already more than a century ago, Sidgwick (1883) proposed using taxes to correct for negative externalities. This concept was later worked out by Pigou (1920), hence the name Pigouvian taxes. In the 1960s another instrument was added to the economist's toolbox: tradable permits, a concept proposed by Crocker (1966) and Dales (1968a,b) and formalized by Montgomery (1972). Since the rise of environmental policy in the 1960s and 1970s, economists have advocated, dare one say lobbied for, these instruments. Despite their efforts, not much has been gained. True, both taxes and tradable permit systems have been implemented (see Stavins (2000)). However, taxes have often been set at such a low level that they have had no effect other than supplying government with revenue. Tradable permit systems are being used more and more, but in comparison to forms of direct regulation, their use has been limited (OECD 1994).

The natural question to ask then is why certain instruments are implemented and others not. As will be clear from the above, the main riddle for the economist is why direct regulation is so popular. The case for taxes and tradable permits seems clear; they are efficient and hence maximize welfare. Direct regulation on the other hand tends to be very crude and will create differences in marginal abatement costs between sources.

Positive political economic theory tries to give an answer to this. In essence, it says that economic agents will try to capture the rents created, deliberately or accidentally, by government action (Tullock 1967; Krueger 1974). This will also be the case in environmental policy. Every instrument has certain characteristics that make it more or less advantageous to different groups. Hence, every group will have its preferred instrument and will be willing to spend time and money to have it implemented.

But how do we know which instrument will be preferred by which group? To answer that question, we need to know what motivates the members of the groups, and if they are represented by interest groups, what the motives of the management of these interest groups are. This seems to be an often forgotten part of the public choice literature on instrument choice. Assumptions about interest group motivation are made in a rather ad hoc way, without much reference to the literature in this field.

In this survey, we will give an overview of both the motives and the preferences for policy instrument of the interest groups involved in and affected by environmental policy. We will then assess whether the public choice literature on interest group preference for environmental policy instrument takes the motives fully into account. As this is not always the case, we will also discuss how the results may change when all motives are taken into account.

This chapter only deals with instrument choice at the national level; we analyze the preferences of interest groups for international emissions trading schemes in the next chapter. However, the current survey has considerable relevance for the analysis of preferences for international instruments. First of all, the motives behind the preferences of the various interest groups will be the same, whether they have to make a choice between national or international instruments. The discussion in this chapter therefore forms the basis for the analysis in the next chapter. Furthermore, as will become clear later, the choice of international emissions trading scheme is related to the choice of national instrument. A discussion of preferences for national instruments is therefore necessary before proceeding with a discussion of preferences for international emissions trading schemes.

This chapter is organized as follows. In section 8.2, we give a short description of the main instruments of environmental policy, which fall into two groups: economic instruments and direct regulation instruments. The next step is to identify the main actors in the rent-seeking game (section 8.3). Having identified the main actors, we continue by discussing their motivations (section 8.4). A large part of this literature stems from the 1960s and 1970s. Especially important in this respect is the paper by Alchian and Demsetz (1972), who model the relationship between the owners or donors of an organization and its management as a principle-agent problem. In section 8.5, we give an overview of the political economy literature on environmental policy instrument choice. An assessment of this literature is given in section 8.6. Here special emphasis is given to the assumptions about the motivations of the different interest groups. Finally, in section 8.7 some conclusions are given.

8.2 Environmental Policy Instruments

Environmental policy instruments are normally divided into two broad categories (Bohm and Russell 1985; Barde 1995; Russell and Powell 1999): direct regulation instruments and market-based instruments. Direct regulation consists of the implementation and enforcement of laws and regulations prescribing objectives, standards and technologies polluters must comply with (Barde 1995). Various direct regulation instruments exist, mostly in the form of standards. Examples are technology standards, emission standards, process standards and product standards. Technology standards specify the use of a certain technology in the production process. Hence, they specify how emissions should be abated, but not by how much. Emission standards can be absolute, specifying a maximum level of emissions for the plant or firm, or relative, where the total level of emissions is allowed to vary with some variable, mostly an input such as fossil fuel, sometimes production. Voluntary agreements can also be counted as direct regulation. Here, the environmental goal is negotiated between government and industry. The industry can then negotiate internally on the distribution of the abatement burden over the individual firms. Since industry is better informed about its abatement costs, voluntary agreements can lead to lower compliance costs than other forms of direct regulation. Although the industry could decide to implement market-based instruments, this has not happened so far. Hence, in most cases, voluntary agreements result in differentiated standards, often a relative standards, for the individual firms. In all, the term direct regulation covers a motley collection of instruments with widely different impact on the regulated industry. Its is therefore important, as Dijkstra (1999) notes, to specify which instrument of direct regulation is analyzed. In the following, we will do so as much as possible. Market-based, or economic, instruments use financial incentives to induce abatement by polluters. Examples are taxes, charges, subsidies, tradable permits, deposit refund systems and liability provisions.

Economists often argue that market-based instruments are more efficient than other instruments (see Baumol and Oates 1988). However, Russell and

Powell (1999) state that this only holds for greenhouse gases and ozone depleting substances, and other fully mixing pollutants. In all other cases, direct regulation may be more efficient than market-based instruments. However, analysis shows that emissions trading can lead to large cost reductions, while not affecting environmental quality, even when the pollution regulated is of a non-uniformly mixing kind (see Klaassen 1996 for an overview).

8.3 Actors

The literature describes many actors and their interest groups that are involved in, or affected by environmental policy. An important group is formed by regulators. This group in turn can be subdivided into politicians and bureaucrats. Another group is formed by those who are regulated. In much of the literature, it is assumed that it is industry that is regulated. Industry, however, is not a unitary actor. It consists of the providers of risk-bearing capital (the owners), the managers and the workers. Besides regulators and industry, a third group is affected by environmental policy: consumers.

To have some influence on policy, affected actors combine in interest groups. The more effective a group is in organizing, the more influence it will have on policy. Here groups consisting of many individual actors with diverging interests are at a disadvantage, since it will be harder for such a group to organize than for a small and homogeneous group (Olson 1965). This tendency is also visible in the groups mentioned above.

Although industry consists of many individual units, it is usually well organized. One reason for this is that it is a rather homogeneous group. Furthermore, government regulation often makes it compulsory for firms within a sector of industry to organize in branch organizations.

Organizations of shareholders do exist, but are often not present in the debate on environmental policy. Shareholder organizations organize shareholders from many different branches. These are affected in different ways by environmental policy. However, through their influence on firm policy, they do affect the behavior of firms. Workers are organized in labor unions. The degree of organization, however, varies considerably between countries and between sectors within a country. Differences in organization between countries are often caused by differences in government policy.

Because of their large number and divergence in interests, consumers are hard to organize. Most policy affects the average consumer only very little. Therefore, the individual benefit of lobbying for a specific policy instrument is too small compared with the costs. However, environmentally concerned consumers are organized in environmental organizations. These organizations are highly present in the environmental debate. This is not to say that consumers as such have no influence on government policy. As voters they can affect who is in power and thereby which policies will be implemented. However, in the literature on environmental policy, voters and their behavior are seen more as a limit to the discretionary powers of politicians than as a direct influence on policy outcomes. Hereby, it is assumed that shifts in government happen mostly as a consequence of bad economic tides. Hence, politicians will take the effect of policies on employment and inflation into account.

So we end up with a number of actors that are important in the environmental policy game. On the side of the regulators, both politicians and the environmental bureaucracy will have an influence. Industry will be directly affected and will therefore try to influence environmental policy. Within industry, three groups can be identified, each with different motives: shareholders, managers and labor unions. Finally, there is a large and diverse group of consumers. However, there are to many with too little individual interest to organize effectively. Therefore, only the environmentally concerned consumers will be represented by environmental organizations.

8.4 Motivations

Before one can analyze the preferences of the different actors involved in and affected by environmental policy, it is necessary to know their motivations. As we will see, the motives of the various individual actors are not that different. After all, they are all just versions of economic man. Besides motives, it is also important to analyze the constraints placed on the behavior of the individual actors within the organizations that affect environmental policy. These two, motives and constraints, result in the behavior of the individuals and organizations.

8.4.1 Legislators

Politicians

There are two basic assumptions in the literature about the motivation of politicians (Persson and Tabellini 2000). In the public choice literature, the standard assumption is that politicians are opportunistic, i.e., they behave in purely self-interested way. In this kind of model, politicians do not derive utility from the policy outcomes, but only from being in office. One version of opportunistic behavior is that politicians are only interested in winning elections (Downs 1957). Such an assumption implies that candidates converge to the same policies.

Another version of opportunistic behavior is that politicians are rent seekers. They try to exploit their political power to receive rents at the expense of the voters (Brennan and Buchanan 1980). In essence, this means that there is a principal-agent problem between the voters (principals) and the politicians (agents). Wittman (1989, 1995) however shows that political competition will bring out an optimal outcome for voters, an idea already voiced by Stigler (1972) and Becker (1983). Hence, as long as there is competition between politicians, the principal-agent problem will not be very large.

The other basic assumption is that politicians have certain ideological preferences. That is, they derive utility directly from policy outcomes (see Wittman 1977, 1983 and Calvert 1985). In this kind of model, the preferences of the politicians determine the outcome. As we will discuss later on, conservative, liberal and socialist ideologies may affect politician gut feeling and rationalization of certain types of market instruments and direct regulation.

In all the above models, lobbying by interest groups can alter the outcome. By providing funds to a candidate, interest groups can increase that candidate's chance of winning. In return they will demand regulation that provides them with rents.

It is quite likely that politicians are risk-averse. In environmental policy, they set certain goals. If these goals are realized, the politicians can expect to benefit from this. However, when the objectives are not met, they may be punished by the voters. For this reason, politicians have an incentive to delegate decisions to agencies, i.e. the bureaucracy, when the expected damage from not realizing the objective is larger than the expected gain from realizing them (Fiorina 1982a,b). It implies that politicians would rather delegate instrument choice to the environmental agency if they consider such decisions as politically risky. Legally that will not be feasible if the introduction of a new type of instrument requires adjustment of existing laws.

The economic literature is in general not very kind to politicians. They are seen as risk-averse opportunists whose main objective is to be re-elected. In some cases however, they are endowed with a conscience in the form of ideology. Often, not even these assumptions are made, and the policy outcome is decided by the relative strength of the interest groups. In that case, the politician is at best seen as the mouthpiece of the winning interest group.

Environmental Bureaucracy

The most influential study of bureaucracies is without doubt Niskanen's Bureaucracy and Representative Government (Niskanen 1971). Although there had been analyses of bureaucratic behavior before, notably Simon (1947), March and Simon (1957), Tullock (1965) and Downs (1967), Niskanen was the first to provide a formal model of bureaucracies on which future work could be based. Niskanen's main assumption is that bureaucrats are budget maximizers. The reason for this is that income, prestige, power and perquisites of the office, which are items entering the bureaucrat's utility function, are positively related to the size of the bureau's budget. In his model, Niskanen assumes that there are only two actors, the (head of the) bureau and the sponsor. In the relationship, the bureau has some distinct advantages over the sponsor in that it has a monopoly of information on production costs and because it can control the agenda. Furthermore, it knows the value the sponsor attaches to every level of output. The result is that the bureaucracy has enormous powers and can force the sponsor to accept a large budget.

If one were to apply Niskanen's theory to environmental policy, budget maximization may be translated as the urge to expand the domain of environment related problems where the bureaucracy can be active. Since budget maximization refers to input, not to output, Niskanen's view implies that the bureaucracy would prefer the instrument that is most bureacratic input intensive.

Niskanen's analysis has been criticized on many grounds. Much of it has centered on the power of bureaucracies. The ability of bureaucrats to control the agenda has been questioned (see Romer and Rosenthal 1978 and Miller and Moe 1983). Another critique centered around the assumption that the bureau had a monopoly on information. In later analyses, the relationship between sponsor and bureau was modeled as a principal-agent problem, where the sponsor as principal has several methods of monitoring and controlling the bureau, either ex post or ex ante (see Breton and Wintrobe 1975, Bendor et al. 1985, 1987 , Banks 1989 and Banks and Weingast 1992).

Johnson and Libecap (1989) test empirically whether the salary of the incumbent personnel at government bureaux increases with an increase in the total number of employees. They found that there was no such relationship. Hence, the quest for a larger bureaucracy does not give higher salary to the incumbent bureaucrats. It is still possible that the utility of the bureau management increases with the bureau size, but then mainly because it gives more prestige and status.

Migué and Belangér (1974) argue that bureaucrats' preferences are not one-dimensional (budget maximization) but have two dimensions: they maximize a utility function with bureaucratic output and discretionary budget as its elements. The discretionary budget is defined as the difference between the total budget and the minimum costs of production. The discretionary budget is available for personal consumption within the organization. There is a trade-off between performing the public task of producing output and personal consumption as given by the discretionary budget (see also Duizendstraal 1999). Niskanen has accepted this critique (Niskanen 1975, 1991). Both Migué and Belangér (1974) and Niskanen (1991) argue that bureaucrats can have a decided preference for the output of their department. The type of bureaucrat that does so has been dubbed 'zealot' by Downs (1967). Frey (1983) gives an overview of a large number of studies that empirically test the difference in cost efficiency between private and public production. In general, the studies show that public production of a good is more costly than private production of the same good. This can be interpreted as evidence for the hypothesis that bureaucrats can secure discretionary budgets for themselves.

For environmental policy Migué and Bélanger's (1974) view on bureaucratic motives implies that the public task of developing and implementing effcetive reduction of pollution is one motive, but next to that the bureaucratic requisites which may be manifold, running from a large staff to good relations with the regulated industry. In sections 8.5 and 8.6 we shall see how such motives work out in terms of preferences for instruments.

Another view on bureaucracy is offered by Stigler (1971) and Peltzman (1976), which builds on the work by Olson (1965). Stigler and Peltzman argue that interest groups and politicians stand to gain from each other. Politicians want to be re-elected. To be re-elected, they need to maximize support. Interest groups will be willing to provide such support in return for favorable legislation. The result, according to Stigler and Peltzman, is that politicians set up bureaux to serve the interest groups. Hence, the bureaucracy is 'captured' by interest groups by design in order to serve the interest of the regulated parties. For environmental policy the theory implies that the environmental bureaucracy is captured by the industry it is supposed to regulate and therefore would design and implement the instrument favored by industry. That goes much further than Migué and Belangér (1974) whose theory only suggests that the bureaucracy would try to come to an agreement with industry on an instrument acceptable to both parties. Elaborations on this theory are given by Becker (1983) and Wilson (1980). They show that capture of bureaucracies is only a special case with many other outcomes possible. Furthermore, other groups such as voters have more influence than Stigler gives them.

Kelman (1981) asserts that the environmental bureaucracy is averse to a new instrument, because it would have to bear the brunt of the organizational learning that a switch to a new system would imply. Rees (1988) also stresses this point. He states that agency resistance to change cannot only be explained by conservatism or management self-interest. There are, often considerable, transitional costs, such as information collection, staff retraining or recruitment and departmental reorganization. These learning costs explain at least partly why there is bureaucratic inertia (see Hanley et al. 1990). Another factor that can be connected with learning costs is that the preferences of bureaucrats may differ according to their training background. It is argued that those with a legal or technical background have a predisposition to command and control instruments, while those with an economic background favor market-based instruments. Both groups would incur learning costs if the instrument implemented is different from the one they were taught about. The theory of bureaucratic conservatism implies that the environmental bureaucracy clings to the policy instruments that are presently in use, that is notably direct regulation through relative standards, and resists new instruments. Woerdman (2002) has elaborated on this dimension for environmental policy instruments in his theory of institutional lock-in.

Another problem is that the management of a bureaucracy has several objectives. Rees (1988) mentions a large number of objectives. Most of these can be categorized either as part of supplying the service the bureau is set up to deliver, as maximizing discretionary spending or as diminishing the interference of the outside world (politicians and interest groups) with the daily business of the bureau. Any policy instrument fulfills these objectives to a different degree. Changing instruments will therefore produce conflicts with the organizational goals. Furthermore, change increases the visibility of the bureau and the amount of public flack it receives (see also De Savornin Lohman 1994). Rees (1988) asserts that the losers under the status quo are only imperfectly aware of their disadvantage and of the benefits they could derive under a different system. Those whose relative position is affected negatively by change are clearly much more aware of it. This implies that the bureau takes the effect of a change in regulation on the regulated industry into account. For environmental policy these considerations imply the same conclusion as the theory of bureaucratic conservatism: stick to the 'tried and trusted' instruments and avoid experiments with new types of instruments.

Several authors argue that the environmental bureaucracy is risk-averse (Nentjes and Dijkstra 1994 and De Savornin Lohman 1994). De Savornin Lohman (1994) argues that environmental regulators are averse to the environmental effectiveness risk because society has given them the job of obtaining physical environmental results. If the goals are not realized, the bureaucracy will be heavily criticized for being ineffective. In the worst case, this could result in the dismissal of the bureaucrats involved. Also, an over-realization of the goals can affect the bureaucracy negatively. The adversely affected parties will in that case demand compensation. Such risk aversion may make bureaucrats averse to new untried instruments, which have not yet proven to be environmentally effective. It implies even more aversion to relatively new instruments, such as environmental taxes, of which a priori the environmental effectiveness is uncertain.

To conclude, bureaucrats may be dedicated to their public task of cleaning up the environment, but they also have their own agenda. Although there are several checks on the self-interested behavior of bureaucrats, it is likely that they will be able to pursue their goal of discretionary budget maximization to some degree. It is also likely that bureaucrats take the effects of regulation on the regulated industry into account, either because they are captured by the industry or because they want to minimize flack. Furthermore, the bureaucracy has an incentive to stick to the policy instruments currently in use, although the background of the bureaucrats may give them a preference for a certain instrument. Last but not least, bureaucrats will be risk-averse because both not realizing and over-realizing the goals set will result in criticisms from interest groups. All these motives may play a role in bureaucrats' assessment of which instrument to choose and implement.

8.4.2 Industry

Often, industry is taken as a unitary actor. However, within industry, several actors with diverging objectives can be distinguished. Here we will discuss three actors: owners, managers, and labor unions.

Owners

Owners provide the firm with risk-bearing capital and expect a return on their investment. More specifically, they will want to maximize profits. If the return is too low, they can withdraw their money and invest it in another way which gives higher profits. Alternatively, they can replace the managers of the firm with some new managers.

Under two circumstances, the owners of the firm may not want to maximize profits (Tirole 1988 and Mas-Colell et al. 1995). When profits are uncertain and the owners are risk-averse, they may prefer not to maximize expected profit. Production plans that are risky may now not be implemented although their expected profit is positive. Another factor that may affect the preference of the owners is that the firm may have an influence on the price and the owners are consumers of the good. In this case, the owners may have an incentive to overproduce to lower the price of the good.

These two circumstances will often play a minor role. First of all, it is easier to insure against risks by diversifying the portfolio than by letting every firm abstain from risk-bearing investments. Secondly, it is unlikely that the owner of (a share of) the firm consumes so much of the good produced that he wants to lower its price. Therefore, in the following, we assume that owners want the firm to maximize profits.

Managers

In many cases, the owners of the firm will not form the management. The shareholders will still be interested in maximum profit, but it might be that the managers have other objectives. Although some parts of the management effort, such as number of hours worked, can be monitored with relative ease, it is less easy to ascertain whether the efforts of the management have been directed to profit maximization. Hence, a principal-agent problem arises where the manager (the agent) has some opportunities to realize his own objectives at the expense of the shareholders (the principals). However, there are some disciplining factors that restrict the managers in their pursuit of pure self-realization.

Several models of managerial behavior have been put forward. A part of the literature endows the manager with a single objective, often under the constraint of a minimum level of profit. In other studies, several objectives enter the utility function of the managers (see also Marris and Mueller 1980 for an overview).

If the compensation of the managers is more dependent on sales volume than on profits, a manager may try to maximize the sales level at the expense of profits (Baumol 1962, 1966). Later, Baumol changed the hypothesis of sales maximization to maximization of the growth rate of sales. Empirical work by McGuire, Chiu, and Elbing (1962) lends some support to the hypothesis that managers' incomes are more closely correlated to sales than to profits. Werden and Hirschey (1980) show that management income is related to both sales and profits. However, other empirical work is less supportive (see Bevars and Siders 1967; Hall 1967 and Baker 1969).

Another hypothesis is that managers maximize the rate of growth of sales revenues (Marris 1963, 1972). Mueller (1972) has put forward an amended version of this thesis. He states that only mature firms are affected by a growth maximization objective of the management.

Managers may also be interested in increasing the number of staff beyond the profit maximizing level. Several reasons can exist for this. First, an increase in the number of staff may increase the chances of promotion for the incumbent staff (Williamson 1963). Second, the management can spread the workload over more people, leading to a lower workload per manager.

One could also expect that managers want to maximize organizational slack. With this is meant that managers are interested in maximizing the means that they can use in a discretionary way (Williamson 1963).

The previous models replace profit in the objectives of managers by another single variable. Another approach is to include a number of arguments in the objective. Williamson (1963) gives an exact specification of the utility function. The items entering the utility function are salary, security, dominance and professional excellence. Dominance consists of three sub-motives: status, power and prestige. He argues that managers have a preference for some types of expense that enhance the objectives of the managers; these expense preferences do not have to be productive. From the utility function, Williamson derives assumptions on the maximizing behavior of managers. First of all, he assumes that managers have a positive preference for staff for the reasons mentioned above. Williamson also assumes that managers have a preference for emoluments. Finally, managers have a positive preference for discretionary profit. With this is meant the profit above the minimum performance constraint set by the market and stockholders. Managers can use this part of the profits in a rather discretionary way.

Does the above mean that management will have its way, and pursue its own goals at the expense of the owners? If the management is not restricted in any way, the answer is yes. However, there are several factors external to the firm that restrict the management in its actions. Holmstrom and Tirole (1989) mention three external disciplining factors: the labor market, the product market and capital markets. The first factor works through the reputation of the management. If profits are consistently low, the reputation of the management will also be low and their value in the labor market will then decrease. The second factor is concerned with the level of competition in the product market. When the product market the firm is operating in is highly competitive, the possibilities for non-profit maximizing behavior are few. In that case, the management has to strive for profit maximization purely to survive. Only when the firm has a certain monopoly power, can management pursue goals other than profit maximization. However, this only holds for individual firms in a sector. With environmental policy, the whole sector is typically regulated with the same instrument. Here, the sector may collectively lobby for an instrument that is not profit-maximizing.

The third disciplining factor is the threat of take-over in which the incumbent management would be replaced (Marris 1963,1964). Furthermore, the owners can devise incentive schemes to keep management on the track of profit maximization. The income of the managers could, for example, be made dependent on the profit earned.

In all, managers seem to have incentives to pursue goals other than profit maximization. However, several constraints, external and internal, will prevent the management from wandering too far astray. There is still reason to believe that the objectives of managers are reflected in the behavior of firms. Clarkson and Miller (1982), for example, conclude from a large body of literature that both profits and firm size are important explanatory variables of firm behavior.

Labor Unions

Workers can be affected in several ways by environmental policy. On the positive side, environmental regulation can improve working conditions. However, environmental regulation can also result in plant closures and lower wages. The representatives of workers, the labor unions, can be expected to oppose measures that affect workers negatively. One major question here, is what the objectives of unions are.

Within the literature, the goals of the unions have been a hotly debated issue. A debate already existed in the 1940s on whether unions could be seen as the maximizers of some objective, as Dunlop (1944) asserted, or whether they could not, but should be seen as political organizations, as put forward by Ross (1948).

Building on Dunlop, several maximizing models have been proposed (see Sapsford and Tzannatos 1993; Pencavel 1991 and Booth 1995 for an overview). Early studies assumed a single maximand such as wages, employment, union membership or rents. However, these models invariably ran into problems, always leaving the labor union with only one member.

More recent theoretical studies endow the labor union with a utility function. A common specification of the union utility function is that it contains both wages and employment. This specification makes it possible to model wage maximization and employment maximization as special cases. Different kind of unions can emphasize one of the objectives more than the other. The result is an intermediary outcome between maximum wage and maximum employment. Alternatively, union utility can be modelled as the sum of the utilities of the individual members (Oswald 1982; Mayhew and Turnbull 1989).

Following Ross (1948), unions can also be viewed as political organizations. The leadership of unions is elected and the results of the negotiations with employers are subject to approval by the members of the union. Therefore, it might be appropriate to model the union in the same way as a political party. Booth (1984) presents a model in which the union managers are concerned with maximizing the probability of re-election as well as wage and employment levels. Union members are only concerned about wages and employment. Booth uses a median voter model to describe the behavior of the management. In this kind of model, under certain conditions, the management will maximize the utility of the median voter (see also Grossman 1983 and Booth and Chatterji 1993).

The leadership of the union may have objectives of their own. Pemberton (1988) includes the preferences of the management in the union's utility function. He argues that the union management has a preference for a large membership because this gives the leadership greater influence and/or wealth. The union leader may also be concerned with his or her tenure, being an elected official (Pencavel (1991)). As in any organization where there is a division between donors and management, a principal-agent problem exists within unions. This allows the management to pursue their own agenda. In comparison with firms, the principal-agent problem in unions will be bigger. It is very hard to monitor whether the output of the union is the maximum output possible. Therefore, there should be ample possibilities for managers to pursue their own objectives.

Burton (1984) presents a model in which the utility of the union leadership is a function of power, social status, income and job security. The first three items are in turn a function of the membership of the union, while the last item is a function of the wages of the union members.

There are only a few empirical studies on union objectives. Farber (1978a, b) analyzes the objectives of the United Mineworkers' Union in the US, while Carruth and Oswald (1985) do the same for the British National Union of Mineworkers. Other studies are by Dertouzos and Pencavel (1981) and Pencavel (1984), who examine the objectives of the International Typographical Union. In the two industries covered, both employment and wages matter to labor unions. There is, however, a large difference in preferences within these industries.

The above shows that labor unions have at least a dual objective. It seems reasonable to assume that unions are not only interested in high wages for their members, but also in a high level of employment. Since managers are difficult to monitor, their preferences will be reflected in the behavior of the union. Hence, it is likely that management will try to increase the membership of the union. As Bain and Elsheikh (1976) and Ashenfelter and Pencavel (1969) show, union membership rises with employment. We would therefore expect that union management is more interested in a high level of employment than in a high wage level for their members.

8.4.3 Environmental Organizations

Not much has been written in the scientific literature on the behavioral assumptions of environmental organizations. Most studies go no further than to remark that environmental organizations want to improve environmental quality. Undoubtedly, provision of environmental quality is the main objective of environmental organizations, but how is this done and do they have other objectives?

In most cases, environmental protection is not provided directly by environmental organizations, but indirectly. They try to induce others, mainly the government, to improve the quality of the environment. Environmental organizations can lobby either through spending money to influence policy makers, or by convincing politicians that taking measures to improve the environment will lead to more votes. The latter will be easier, the higher the membership of the environmental organization (Svendsen 1998b). To raise the level of contributions per member and to raise the level of membership, the environmental organization has essentially two strategies. Organizations that are successful, i.e. organizations that provide a high level of environmental quality, will see their membership and contributions increase. Furthermore, direct fundraising will also increase both factors. If the management of the environmental organization only has the interests of the donors at heart, it will engage in fundraising up to the point where the marginal benefits equal the marginal costs.

However, managers may have their own objectives, although it is likely that they do have a preference for high environmental quality. The question is whether managers of environmental organizations have opportunities to realize their own objectives, and what those objectives are.

Most, if not all, environmental organizations are non-profit organizations. There are three main reasons for organizing in this way (Rose-Ackerman 1996). First of all, by choosing the form of a non-profit organization, gifts cannot be converted into profits for the owners. In this way, the donors are assured that it is their interests that are being served with the donated funds (Hewitt and Brown 2000). Secondly, non-profit organizations may have less incentive to misrepresent the quality of the service provided than for-profit organizations do. Thirdly, non-profit organizations may foster experimentation and provide the possibility of putting into practice unpopular or extreme ideologies. The first factor means that non-profit organizations are better at competing for gifts than for-profit organizations. The second and third factors are important in the case of environmental organizations, because the product provided by them can to a large degree be characterized as a public good. Moreover, it is a public good of which it is hard to determine both quantity and quality.

Although their organizational form should lead people to trust environmental organizations, it also leads to some problems. Non-profit managers have little incentive to manage their organizations in an efficient manner since no one has a claim on the profits. Hence we can expect that shirking is more likely to occur in non-profit organizations than in for-profit organizations (Alchian and Demsetz 1972 and Rose-Ackerman 1996). In general, we can expect the principal-agent problem to be highly acute. Not only are there few methods for disciplining the managers, but as mentioned before, the output of environmental organizations is hard to monitor.

As with bureaucrats, it is very likely that the utility functions that managers of environmental organizations will maximize contains the discretionary budget as one of its components (Niskanen 1971 and Migué and Belangér 1974). Furthermore, as with labor unions, it is likely that the managers of environmental organizations have a preference for a high level of membership. This will give them status and more influence in the political arena.

If the management is only interested in discretionary spending, fundraising will occur up to the point where the marginal benefit of fundraising is equal to zero (Hewitt and Brown 2000). However, it is also likely that many of the managers themselves have a preference for the output of their organization; they are so called 'zealots'. In that case, fundraising may be done beyond the point where the marginal benefit is equal to the marginal costs, but not to the point where it is zero. Hewitt and Brown (2000) have tested whether managers of environmental organization are only interested in discretionary spending, or whether they also derive utility from the output of the organization. They find that managers of environmental organizations derive positive marginal utility from discretionary spending. Although they do not go so far as to conclude that the managers maximize discretionary spending, they mention that their results could be explained as such.

Environmental organizations always press for lower levels of pollution. Indeed, they have always maintained a symbolic goal of zero pollution (Svendsen 1998b). This implies that any emission level above the policy goal will be unacceptable to environmental organizations. The result is that they are risk-averse (Nentjes and Dijkstra 1994). To be more specific, they are downward risk-averse, since an emission level below the goal can be explained as a success for the environmental organization.

To be effective at lobbying for environmental protection, environmental organizations need a large number of donors and a high level of income.

The organization can attract donors by being successful and by engaging in fundraising. Since environmental organizations can expect to be confronted by industry, they may have more success by supporting the same policy instrument as industry does (Svendsen 1998b). If the management has a preference for discretionary spending, it will show up in excessive expenditure on fundraising. This will increase membership, but will decrease the level of services provided. To conclude, the objectives of the environmental organization are to provide environmental quality and to increase membership. On top of this, they are risk-averse.

The literature discussed in this section shows some clear tendencies, which run through almost all interest groups. First of all, managers have a preference for discretionary spending and for the size of the organization they work for. Second, there is a principal-agent problem in all organizations. The level of manager discretion then depends on how well the principals, i.e. owners or donors of the organization, can monitor and control the manager. Hence, managers will have a large influence on the policy of the organization in labor unions and environmental organizations and least in firms operating in perfectly competitive markets.

8.5 Preferences

We described above the behavioral assumptions of the different actors in the environmental rent-seeking game. In this section, we give an overview of the literature that discusses the preferences of interest groups for environmental policy instruments. The aim of this literature is to explain which instruments are used, as opposed to much of the environmental economics literature, that analyzes which instrument is optimal.

8.5.1 Legislators

Politicians

In most analyses of instrument choice, the preferences of politicians are not taken into account. The implicit assumption is that the policy is determined in a contest between interest groups. The interest group that is best at rent seeking wins the contest and will see its preferred instrument implemented. However, there are a few studies that do analyze the preferences of politicians and how these preferences affect the outcome.

Verbruggen (1991) assumes that the main interest of politicians is to maximize public support in order to be re-elected. Since environmental issues are of high concern to the public, politicians will wish to attain certain environmental goals. However, in doing this they are constrained by two conditions. First, the policy should have no harmful adverse effects on income distribution and employment. Second, the international competitiveness of domestic industry should not be adversely affected. Furthermore, to set environmental policy, the government will need information that can only be provided by the polluters. This creates a discussion and negotiation platform. Therefore, Verbruggen argues that the industry lobby will be very effective. The result is that politicians will choose direct regulation or voluntary agreements with industry. If emission charges are used, the revenue is often recycled to the regulated industry.

Hochman and Zilberman (1978) conclude that because relative standards result in higher output and lower prices, they contribute less to unemployment and inflation while achieving an acceptable environmental threshold. For these reasons, politicians may prefer relative standards to emissions charges.

In their analysis, Nentjes and Dijkstra (1994) split the group of politicians into Members of Parliament and the minister. The description of the political process in their study relates strongly to the situation in the Netherlands, although it is also applicable to other countries with similar political systems. Since in the Netherlands, voters vote for a party and not a single candidate, Nentjes and Dijkstra do not take the single candidate, but the political party as the decision-making unit. The assumption is that political parties want to maximize the number of parliamentary seats. Besides this, Nentjes and Dijkstra also assume that ideology is important in politicians' preference of environmental policy instruments. They identify four political blocks with different emphases on the welfare of workers, wealth holders and the environment. The final ordering of instruments of a party is then equal to the preference of the interest group that comes first in the political party's ordering. This is a rather crude method of assigning a preference for environmental policy instruments to political parties. Furthermore, although Nentjes and Dijkstra explicitly mention that parties aim to maximize seats in parliament, they assign preferences purely with regard to ideology.

Nentjes and Dijkstra (1994) endow the minister with only one objective: to translate the government policy programme into concrete proposals. Government in the Netherlands always consists of a coalition of parties. Therefore, Nentjes and Dijkstra construct from the preferences of the parties, preferences of possible coalitions. Furthermore, they argue that the environmental bureaucracy has considerable power in a system such as the Dutch one. In this way, Nentjes and Dijkstra show that it is very likely that industry will be regulated through direct regulation.

An extensive overview of the preferences of legislators is given by Keohane et al. (1997). However, they do not always distinguish between politicians and bureaucrats. A first argument given by Keohane et al. is that legislators and their staff are predisposed to favor direct regulation by their predominantly legal training. Furthermore, unfamiliar instruments require legislators to invest time in learning about them. This gives a bias in favor of existing instruments, which are mostly command and control instruments.

Another factor important for the preference of politicians is uncertainty. Here, we not only refer to uncertainty about the level of emissions, but also about the distribution of costs and benefits among the affected parties. Here the flexibility of market-based instruments is a disadvantage, since they give uncertainty about the distributional effects and may create hot spots (McCubbins and Page 1986). Especially in countries where politicians represent a certain geographical area, they may be more concerned with the distribution of costs and benefits than with overall efficiency (Hahn and Stavins 1991). The costs also include the possibility of closure and relocation of firms and the local unemployment associated with it (Hahn and Noll 1990). If legislators want a certain distribution of benefits and costs, they will have greater opportunity to do so with direct regulation. This after all gives them the possibility of prescribing rules and procedures that favor one group over another (McCubbins et al. 1987 and Keohane et al. 1997).

A divergence from current policies creates both winners and losers. However, the losers will be more aware of their loss than the winners of their gain. Moreover, it is not the real costs and benefits that are important, but the perceived costs and benefits (Hahn 1987). For this reason, politicians are likely to prefer direct regulation because they tend to hide the costs of regulation, whereas market-based instruments tend to give a focus on the costs (Keohane et al. 1997).

Keohane et al. (1997) also stress the importance of ideology. Here they cite Kelman (1981), who finds that Republicans support the concept of charges, perhaps not so much for their efficiency, but more because they use markets and give less intervention from government. Democrats on the other hand, did not support charges, again largely on ideological grounds.

In most analyses, politicians are non-existent. Which policy instrument is implemented is then determined in a contest between interest groups. If politicians are present in the analysis, they are mostly depicted as support-maximizing and risk-averse. On the basis of these assumptions, most authors conclude that politicians will prefer direct regulation. Endowing politicians with an ideology can either reinforce this conclusion, or weaken it.

Environmental Bureaucracy

We concluded above that the environmental bureaucracy has preferences concerning its budget and discretionary costs. Furthermore, it is likely that at least some of the bureaucrats have a preference for environmental quality, but at the same time take the effect of the regulation on the polluters into account. The background of the bureaucrat, legal or technical on the one side or economic on the other, may have an influence on the bureaucrat's preference of instruments. Last but not least, bureaucrats are risk-averse. Several of these preferences are mentioned in the literature on the choice of environmental policy instrument.

From several Dutch government reports, Nentjes (1988) concludes that the main objective of the environmental bureaucracy is certainty of effectiveness. This objective can be seen as a result of the risk-aversion of the bureaucrats. Direct regulation gives a clear prescription of either the measures to take or the level of abatement to attain and furthermore gives the bureaucracy a high level of control over the regulated industry. Therefore, the environmental bureaucracy will prefer direct regulation (see also Frey 1992 and DeClerq 1996).

Nentjes and Dijkstra (1994) give the most comprehensive analysis of environmental bureaucrats' preferences. They assume that the main objective of the bureaucrats is the certainty of realizing the environmental target. Next to this, two secondary objectives are identified. Nentjes and Dijkstra argue that the bureau cannot be ignorant of the costs of the regulation to polluters. Furthermore, bureaucrats may have internal goals such as organizational slack, which is reflected in a preference for a large input of bureaucratic labor.

For each of the objectives, they rank the instruments. They argue that direct regulation gives the bureau the largest level of control, with grandfathered tradable permits taking second place. Although tradable permits give certainty of realizing the overall objective, they do not give the bureaucracy control over the pollution per firm. With regard to cost for the regulated industry, Nentjes and Dijkstra take the reduction in number of firms due to environmental policy as the relevant indicator for the bureaucracy's view of cost to industry. The effect is the same for all market-based instruments and is more negative than the impact of direct regulation. Finally, on the issue of labor input, charges and grandfathered tradable permits are ranked highest for being the most labor intensive instruments. Overall, they conclude that the environmental bureaucracy will prefer direct regulation to all other instruments.

Keohane et al. (1997) also arrive at the conclusion that the environmental bureaucracy will prefer direct regulation. As reasons they state that the bureau will be familiar with this form of regulation, and shifting to another instrument will require them to gather much new information about the working of these instruments. Moreover, their current knowledge may become obsolete when a new instrument is chosen, which leads to job insecurity. Finally, market-based instruments imply a scale down in the role of the agency by shifting decision making from the bureau to the firms. This undermines the prestige of the agency and the job security of the bureaucrats (see also Hahn and Stavins 1991).

Liroff (1986) finds that the environmental bureaucracy is not a homogeneous group. Instead, two groups can be distinguished: the command minimalists and the command expansionists. Command minimalists will support economic instruments because they give most freedom to industry, both in determining how much to abate and how to abate. Command expansionists on the other hand want to have as much control over the polluters as possible. Therefore, they will support direct regulation. Note that the same disposition was found among politicians.

Christoffersen and Svendsen (2000) argue that bureaux have influence on the spending of the taxes that are collected by the bureau. If this is the case, bureaucrats may be more inclined to use revenue-raising instruments such as taxes and auctioned tradable permits.

Dijkstra (1999) presents empirical evidence on the preferences of Dutch environmental bureaucrats. He notes that there is considerable disagreement within the bureaucracy on the issue of instrument choice. A general tendency seems to be that the bureaux see no need for large changes in the use of instruments, which predominantly are direct regulation through environmental standards and covenants. At most, the current instruments can be made more flexible. However, there is a large division between the two groups within the bureaux. The main issue is how much responsibility industry can handle in reducing emissions. One group only wants to set emission levels and leave the implementation to industry, while the other group stresses that this responsibility cannot be left to industry. It is not certain whether these differences in opinion are correlated with educational background. The level of contact with the regulated industry may also play a role. The closer the contacts, the more 'captured' the bureaucrat is.

The literature that discusses bureaucratic preferences sees bureaux as important in the setting of environmental policy. They are however, mostly seen as conservative in that they have a preference for the status quo. Because of the high costs of adapting to new instruments and the uncertainty connected to economic instruments, bureaucrats prefer direct regulation. The survey of Dijkstra (1999) however, shows that there may be diverging opinions within the bureaucracy, with one group supporting economic instruments and the other direct regulation.

8.5.2 Industry

Industry is usually assumed to be one entity with one unified goal: profit maximization. In some cases, workers are treated separately. However to our knowledge, the distinction between shareholders and management has never been made explicitly.

Shareholders

If one assumes that firms maximize profits, the positive political economy explanations of the demand for regulation by industry can be divided into three categories (Keohane et al. 1997): (1) preference for an instrument can arise from lower aggregate costs to industry, (2) the instrument awards industry with rents and places a barrier to entry, and (3) there are differences in the costs of compliance across firms within the industry.

In general, industry will prefer instruments that have low aggregate costs. Although market-based instruments are most cost-effective, it is not certain that they will be preferred by industry (Keohane et al. 1997). Taxes and auctioned tradable permits give high costs to industry because with both instruments a price is paid for residual emissions, which can easily exceed cost savings arising from more efficient allocation of abatement. This is not the case with grandfathered tradable permits and direct regulation, which is why industry will prefer these instruments.

Another factor may also make industry prefer direct regulation. It is often argued that industry has more influence on policy with direct regulation than with other instruments. According to Bohm and Russell (1985), direct regulation is more uncompromising. Therefore, the government is more inclined to listen to the views of the polluters before any action is taken. Industry influence will be especially large when information about abatement costs is needed by the government. This would be the case when regulation is firm-specific or when an aggregate emission target has to be translated into a tax. A firm then has a certain bargaining power, which it can use to obtain a more lenient standard or tax. However, since the precise setting of a tax requires a large amount of information, this is never done. Mostly, the level of a tax is based on rather crude calculations. This is not to say that firms will have no influence on an environmental tax. As is shown by Andersen (1996), DeClerq (1996) and Svendsen (1998a), industry often has a large influence on the design and level of a tax.

The above suggests that industry will prefer direct regulation and perhaps grandfathered tradable permits. The advantage of the latter is that they are efficient, give industry a free choice in how to abate and do not give firms the cost of residual emissions. Although direct regulation is not efficient, and in many cases does not give firms a free choice of abatement technology, it gives low costs to industry and may be prone to industry influence.

Several studies have addressed the question of preference for environmental policy instrument directly. The first to do so were Buchanan and Tullock (1975). They showed that, in a partial equilibrium model with perfect competition, the profits of the polluting industry are higher with direct regulation than with an emission tax. The form of direct regulation used in their model is a cap on firm emissions. Since they assume that there is no technology to remove the pollution, the cap on emissions effectively becomes a cap on production. In this way, the price of the good produced is increased. In the short run, the firm is better off with the cap than with taxes, because with taxes it has to pay for the residual emissions. The firm may even make a profit with emission ceilings, both in the short run and in the long run. This occurs when the reduction in production causes a proportionally higher rise in the price of the good. Without entry, the firm may even experience profits in the long run.

Dewees (1983) provides another comparison of instruments. Contrary to Buchanan and Tullock (1975), Dewees allows for the possibility that emissions can be reduced per unit of output. His analysis is somewhat out of line with the main body of the literature in that he assumes that the aim of government policy is to reduce emissions per unit of output. Dewees considers three instruments: an emission charge per unit of emissions, tradable permits, and a relative standard. He shows that when capital can be transferred without cost, shareholders will never lose. Moreover, with grandfathered tradable permits, the rent received at the initial distribution of the permits increases the profits. Hence, in this case, shareholders prefer grandfathered tradable permits. Also when capital is immobile, shareholders may prefer grandfathered tradable permits. However, relative standards may perform equally well. The preference for grandfathered tradable permits is based, as in Buchanan and Tullock (1975), on the fact that the firm receives rents from the initial distribution of permits. Although Dewees (1983) is in many regards a step forward in comparison to Buchanan and Tullock (1975), Dijkstra (1999) shows that Dewees's analysis is flawed on many points.

The most comprehensive treatment of preferences for environmental policy instrument is given by Dijkstra (1999). In a partial equilibrium model with perfect competition, he discusses the effects of four instruments: relative standards, emission ceilings, emissions charges and tradable permits (both grandfathered and auctioned). In the model, it is assumed that there are no barriers to entry. Dijkstra finds that in the short run, emission ceilings, charges and tradable permits have the same effect on production and product price. Only relative standards give a different outcome. More specifically, with the same level of pollution, a relative standard gives a higher level of production and consequently a lower product price (see also Hochman and Zilberman 1978; Helfand 1991 and Ebert 1998,1999). In the long run, market-based instruments give the highest welfare. Dijkstra also arrives at the conclusion that shareholders should prefer grandfathered tradable permits because they present a rent, which is given free.

The conclusion of the formal models is clear. When the goods market is fully competitive and entrance is restricted, both direct regulation and grandfathered tradable permits create a rent, which is awarded free to the shareholders. Therefore, they have a preference for these instruments. With free entry, only grandfathered tradable permits create a rent. Shareholders therefore prefer grandfathered tradable permits to all other instruments. The next instruments in the preference listing are emission ceilings and relative standards. At least in the short run, these create rents. Furthermore, with emission charges and auctioned tradable permits, a price is paid for the residual emissions, while this is not the case with ceilings and relative standards.

The analysis by Dijkstra (1999) clearly shows that with free entry, firms subjected to direct regulation will not receive rents in the long run. Only if the instrument creates a barrier to entry will such rents persist. Such a barrier could exist if new plants were subjected to stricter environmental standards than existing ones. Stricter standards for new plants may be efficient if the cost of abatement for such plants is lower than for existing plants. However, when the standards are very tight for new plants, a real barrier to entry exists. Tietenberg (1985) describes how under the Clean Air Act, new or modified sources are subject to stricter standards than existing ones (see also Maloney and McCormick 1982 and Svendsen 1998b). It is however, not clear whether existing differences in standards between existing and new firms comprise a barrier to entry, or whether they only reflect differences in costs of abatement.

There is some difference in opinion in the literature on whether grandfathered tradable permits create a barrier to entry. With grandfathering, existing firms receive permits for free while new firms have to pay for them. Hence, incumbent firms do not have to pay for (all) their residual emissions, while new firms do. This would then be an entrance barrier (Keohane et al. (1997) and Svendsen (1998b)). However, Koutstaal (1997) and Dijkstra

(1999) argue that this in itself does not form a barrier to entry. The grandfathered permits constitute an opportunity cost to the recipient because it could have sold them on the market. Koutstaal and Dijkstra mention that grandfathering will result in an entry barrier when new firms have to incur transaction costs to purchase the permits or when the capital markets work imperfectly.

With tradable permits, existing firms can raise a barrier to entry themselves by colluding. They could agree not to sell permits to new firms or to raise the market price (Tietenberg (1985) and Misiolek and Elder (1989)). When there are many firms in the market however, this is unlikely to happen. Furthermore, the government can deter this kind of behavior by selling a certain portion of the permits available each year, as is done in the US sulfur trading program. But above all, the national anti-trust authority has the task to detect, punish and prevent such collusion.

Maloney and McCormick (1982) argue that environmental regulation can increase the value of some firms in the regulated industry, while lowering the value of other firms. In general, the value of low-cost firms is expected to increase, while that of high-cost firms will decline. They also provide some empirical evidence showing that this occurred in several cases of environmental regulation.

Because of the differences in costs of abatement, firms that are affected less than average by a particular policy instrument may support it because it gives them a competitive advantage (Leone and Jackson (1981) and Oster (1982)). There is some empirical support for this suggestion (see Keohane et al. (1997) for an overview and Maloney and McCormick (1982)). However, Leone and Jackson (1981) found that the intra-industry transfer argument is not very important.

The theoretical literature on industry preferences for environmental policy instrument is not conclusive. It points to both direct regulation and grandfathered tradable permits as the favored instruments of industry. Reasons to prefer direct regulation are: (1) direct regulation leads to lower costs for the polluters. The reason is that with taxes and tradable permits, a price is paid for the residual emissions, possibly exceeding the efficiency gains, which is not the case with direct regulation; (2) industry has more influence on policy with direct regulation than with market-based instruments; (3) direct regulation creates rents that are distributed free to the industry; and (4) because abatement demands are usually less stringent for existing plants than for new ones, direct regulation can lead to a barrier to entry, benefiting the incumbent firms.

Reasons to prefer grandfathered tradable permits are: (1) tradable permits are efficient and hence lead to low costs for the industry as a whole; (2) grandfathered tradable permits create a rent; and (3) they also could create a barrier to entry (although this is debatable).

When maximizing profits is the objective, the conclusion derived from formal models is that industry should prefer direct regulation or grandfathered tradable permits, because both create a rent. However, several qualifications should be made. First, the result that direct regulation leads to rents will only hold in the long run if there are barriers to entry. If this is not the case, new entrants to the market will compete the rents away. Second, what is direct regulation? Buchanan and Tullock (1975) and Leidy and Hoekman (1994) take emission ceilings, while Dewees (1983) uses relative standards. Only Dijkstra (1999) analyzes the effect of both forms of direct regulation. Dijkstra (1999) shows that in the long run there is no difference in profitability between ceilings and relative standards. Third, only Dewees (1983) and Dijkstra (1999) analyze some forms of both direct regulation and tradable permits. Both authors conclude that industry should prefer grandfathered tradable permits to direct regulation.

A few surveys exist that try to shed light on interest group preferences for environmental policy instruments. Kelman (1981) was the first to conduct such a survey. In the survey, respondents only had a choice between direct regulation and charges. Kelman found that industry was clearly opposed to charges; 85% of the respondents were against them. At the same time, it showed that industry was not very well informed about charges.

Wallart and Bürgenmeier (1996) conducted a survey among major Swiss firms, which also concentrated on emissions charges. They found a surprisingly large acceptance of charges by industry. In all, two-thirds of the polluting firms were in favor of charges. However, Dijkstra (1999) conjectures that the survey by Wallart and Bürgenmeier (1996) may have been wrongly designed, leading to the high acceptance of charges.

In a survey of American and Danish interest groups, Svendsen (1998b) finds some differences between the industrial sectors in the two countries. In the US, both industry and public electricity companies favor grandfathered tradable permits because they perceive this instrument as both efficient and flexible. Danish industry on the other hand prefers voluntary agreements; the industry wants to take voluntary action to prevent state intervention. Taxes are rejected because they will bring higher production costs. Grandfathered tradable permits are seen as a compromise solution. In contrast to industry, Danish public electric utilities prefer taxes. In general they prefer market-based instruments, but assess that Denmark is too small to have a viable market in permits. The reason for this difference between industry and public electric utilities is, according to Svendsen, that the utilities, being heavily regulated, share interests with the state.

Dijkstra (1999) conducted a survey among Dutch interest groups in which industry shows a preference for relative targets as opposed to absolute ones. However, in general there is doubt in industry about market-based instruments. Taxes especially are seen as detrimental to international competitiveness. Industry also expects problems with the initial distribution of tradable permits. The only industrial organization giving a direct preference ordering preferred relative standards. Grandfathered tradable permits come in second place; charges and auctioned tradable permits command very little support. In comments given to the survey, several industrial organizations express a preference for covenants or voluntary agreements because they are flexible and give a minimum of government interference. Tradable permits are seen as a complement to voluntary agreements.

The outcome of the surveys is that American industry prefers grandfathered tradable permits, while European industry prefers voluntary agreements. Although more attention has been given to voluntary agreements in the economic literature lately, the positive literature on environmental policy choice has mostly ignored them. Voluntary agreements are however very attractive to industry. Through voluntary agreements with the government, industry can influence both the level of emissions and the policy instrument used (Dietz and Van Der Straaten (1992)). Hence, voluntary agreements provide industry with ample opportunities for rent-seeking (Verbruggen (1991)).

In all, the theoretical studies seem to be supported by the surveys. According to the theoretical studies, shareholders should prefer direct regulation or grandfathered tradable permits. The surveys shows that these are the preferred instruments of industry. However, neither the theoretical, nor the empirical analyses give a unanimous result.

Labor Unions

The preferences of workers are not often analyzed. One reason for this is that labor unions are not seen as very influential in the environmental debate. Environmental policy is not the core interest of unions, and hence, they often have no policy on this issue. When the preferences of unions are discussed in the literature on environmental policy choice, it is almost always assumed that unions maximize employment.

Hochman and Zilberman (1978) make a connection between output and employment. They examine the impact of taxes and relative standards and conclude that the latter result in higher output and lower prices. Therefore, workers will prefer relative standards.

Another analysis is offered by Dewees (1983). He assumes that the government wants to reduce emissions per unit of production. Hence, total production and thereby total emissions can vary per instrument. When capital is flexible, Dewees finds that employment will be highest when relative standards are used and lowest when market-based instruments are used. The reason for this is that in the model, a fixed portion of operating costs goes to labor. With market instruments, a part of the firm's revenue is forwarded to the government with taxes, or to the shareholders with tradable permits. With non-flexible capital, there is no difference in the effect on employment between the instruments.

In a model that is essentially the same as that of Buchanan and Tullock (1975), Leidy and Hoekman (1994) include an analysis of the preferences of workers. They argue that workers will prefer emission ceilings. Since output is inefficiently high in the long run under emission ceilings, industry employment will be higher with this instrument. Furthermore, industry profits are highest under emission ceilings. Workers will try to capture a part of these profits in the form of higher wages. Finally, under direct emission ceilings, possible lay-offs will occur at all firms, while with charges, job losses only occur in connection with firm closures. The former option is seen as more equitable.

Dijkstra (1999) analyzes the preferences of workers in a partial equilibrium model. His assumption about worker preferences is that they are mostly interested in employment. Dijkstra argues that in the short run, employment will be highest with relative standards and lowest with market-based instruments. This follows from the level of production, which is highest under relative standards and lowest under market-based instruments. To compare employment levels in the long run, Dijkstra assumes that labor costs are a fixed percentage of operating costs, hereby following Dewees (1983). The result is that employment will be lowest with market-based instruments. Depending on the elasticity of demand for the produced good, relative standards or emission ceilings give the highest employment in the long run.

Nentjes and Dijkstra (1994) assume that workers prefer the policy instrument that maximizes employment in the regulated industry and the stability of jobs within firms. They furthermore assume that the industry is fully competitive and that there is a constant capital/labor ratio. Nentjes and Dijkstra argue that workers prefer direct regulation to market-based instruments. With direct regulation, total employment in the industry is higher than with market-based instruments and more firms stay in the industry, meaning that fewer workers have to shift firm.

Keohane et al. (1997) use essentially the same assumptions as Nentjes and Dijkstra (1994); unions seek to protect jobs and are therefore opposed to instruments that lead to plant closures or industrial dislocations. Keohane et al. (1997) mention that direct regulation standards have generally been tailored to protect aging plants, which would not be easy with market-based instruments. Hence, they conclude that labor will prefer direct regulation to market-based instruments.

Only Dijkstra (1999) gives empirical evidence on workers unions' preferences for environmental policy instruments. The two Dutch unions included in his survey do not give a unanimous preference ordering. One union (CNV) prefers emission ceilings, with charges taking second place. Tradable permits, whether auctioned or grandfathered are least preferred. The other union (FNV) states a general preference for market-based instruments, although it has some doubts about their practicability. Furthermore, the FNV states that a combination of instruments often works best in practice.

The theoretical studies lead to a clear conclusion. Workers prefer direct regulation because this gives the highest level of employment. The empirical evidence, however, is less conclusive.

8.5.3 Environmental Organizations

In the literature, environmental organizations are thought of as guardians of the environment. Their main, if not only, objective is to reduce emissions.

In the model by Dewees (1983), the government sets a standard per unit of production. As a result, the instrument that gives the highest output also gives the highest total level of pollution. Since market-based instruments give the lowest output, Dewees argues that environmentalists should prefer these to direct regulation.

Other arguments related to the level of emissions are given by Dijkstra (1999). Environmentalists will be against tradable permits, because they give firms the possibility of selling permits when the firm was going to reduce emissions anyway. This could be in connection with the start of a new plant replacing an older more polluting one, or when the firm goes out of business. In these cases, the environmental movement would argue that total emissions should be reduced.

Most models of environmental policy instrument choice take the target of emissions to be an absolute one. In that case, environmental organizations should be indifferent between instruments. However, if they are risk-averse, they may have a preference ordering for the instruments. Leidy and Hoekman (1994), for example, argue that environmental organizations will prefer emission ceilings. Like Buchanan and Tullock (1975), they assume that emissions can only be reduced by reducing output. In the model, firms will have an incentive to produce more than their ceiling. However, perfect monitoring ensures that they will not. Furthermore, the firms in the industry will receive a rent from regulation, which will increase their profits. Therefore, they will be able to pay for an eventual clean up if they violate the regulation. Contributing to this is that no firm will leave the market as a result of the regulation.

Nentjes and Dijkstra (1994) also assume that environmental organizations are risk-averse. They argue that only emission charges give uncertainty about the aggregate emission level. Nentjes and Dijkstra therefore use another criterion to come to a preference ordering. They argue that if environmental organizations assess that they are rather strong at lobbying, they may have a preference for instruments that give revenue. Therefore, Nentjes and Dijkstra conclude that environmental organizations prefer auctioned tradable permits, since these give both a revenue and a high certainty of realizing the objective.

Besides arguments based on the emission level or risk aversion, many of the arguments used by environmental organizations are moral or ethical. These arguments are always directed against the use of market-based instruments.

One of these arguments is that it is wrong to use market-based instruments because the environmental problem is caused by a failure of the market (Nentjes (1988)). It is furthermore said that marked-based instruments give polluters a license to pollute (Kelman (1981)). After all, with tradable permits or taxes, firms can emit as long as they are willing to pay for it. Worst is the situation with grandfathered tradable permits, where the government gives polluters a right to emit for free. Environmental organizations argue that the right to environmental quality belongs to the public and not to the polluters. Furthermore, firms should reduce emissions because it is wrong to pollute, not because they can earn money (or save costs) doing so (Dijkstra (1999)). Finally, environmentalists see the environment as priceless. Therefore it is morally wrong to put a price on it through marked-based instruments (Kelman (1981)).

Environmental organizations may also oppose market-based instruments for strategic reasons (Keohane et al. 1997 and Dijkstra 1999). When permits are given the status of property rights, it will be very hard to reduce emissions to a lower level in the future without giving compensation to the polluters (Hahn and Noll 1990). This can be remedied by explicitly stating that the permits do not represent a property right, or by making the permits only valid for a specific period of time (Keohane et al. 1997). Taxes will also be hard to increase, since this instrument raises strong resistance from industry.

One reason for environmental organizations to support market-based instruments is that they lower overall costs of compliance. Therefore, it could be easier to reduce emissions to a lower level than with direct regulation. Furthermore, as already mentioned above, taxes and auctioned tradable permits yield a revenue. This could be earmarked for environmental protection (Dijkstra 1999).

Keohane et al. (1997) make a connection between the preference of instrument by environmental organizations and the level of membership and thereby the budgetary resources of the organization. If the support for a particular instrument attracts members, increases donations or increases the visibility and prestige of the organization, it may affect its preference of instrument. Hence, if an environmental organization can distinguish itself by supporting a certain instrument, it may be profitable to do so. Keohane et al. (1997) give the example of the Environmental Defense Fund (EDF), which in contrast to other environmental organizations, supports tradable permits.

Three surveys exist in which the attitudes of environmental organizations toward environmental policy instruments are described. The first one was conducted by Kelman (1981). He finds that environmentalists are far from unanimous on the issue of charges. Of the 19 environmentalists interviewed, 32% supported charges, 16% favored experiments with taxes, while 37% were against charges.

Svendsen (1998b) finds that US environmental organizations support tradable permits. He argues that they have abandoned their philosophical objections to market-based instruments because they need success. Environmental organizations have realized that environmental improvement can only come about with the cooperation of the polluters. Since the (US) polluters prefer tradable permits, so do the environmental organizations (see also Svendsen 1999). Svendsen (1998b) finds that Danish environmental organizations support environmental taxes. However, they remain skeptical about tradable permits. Svendsen attributes this to a lack of knowledge.

In a survey of Dutch interest groups, Dijkstra (1999) finds some support for market-based instruments by environmental organizations. However, as in the survey by Kelman (1981) there is considerable disagreement among environmentalists as to which instrument is best. Furthermore, a mix of instruments is often proposed. However, there is much agreement among environmental organizations that the target of policy should be stated in absolute terms and not in relative ones. This would imply emission ceilings or tradable permits.

The above shows that environmental organizations should either prefer emission ceilings or auctioned tradable permits. Both instruments give a high certainty of realizing the abatement goal set. However, from the point of view of environmental organizations, there are some important differences between them. Tradable permits are less preferred for moral and ethical reasons. On the other hand, auctioned tradable permits give a revenue that could be used for further environmental improvements and grandfathered tradable permits may make it easier to come to an agreement with industry. In contrast to tradable permits, emissions ceilings allow control of individual polluters. The empirical evidence is as inconclusive as the theoretical literature.

The literature discussed in this section gives some indications as to why market-based instruments are not used very much in environmental policy. First of all, none of the groups mentioned has a preference for taxes. Actually, this lack of support for taxes is rather surprising. They are an important source of revenue for the government and it can be expected that politicians and bureaucrats have a large influence on how these revenues are spent. Hence, one would expect them to have a preference for this instrument. Also other interest groups could have an interest in taxes. Labor unions, for example, could argue that the revenue of environmental taxes should be used to lower distortionary taxes on labor. Environmental organizations could try to have the proceeds of environmental taxes earmarked for further environmental improvements. However, such arguments are not put forward in the literature. What is emphasized is that taxes give high uncertainty about the realization of the policy objectives. It is mainly for this reason that taxes are rejected by the groups mentioned.

Tradable permits only receive support from owners of firms and partly from environmental organizations. It must be noted though that owners support grandfathering of permits, while environmental organizations prefer auctioning of permits. The other interest groups reject tradable permits for several reasons. A prime problem is that tradable permits are a new instrument. Hence, all actors would incur learning costs when this instrument is implemented. Furthermore, tradable permits give almost no possibility for government influence on the polluter. Although this is seen as a blessing by firms, politicians and bureaucrats would prefer to have influence on the level of emissions and the abatement techniques used by individual firms. Although environmental organizations should prefer tradable permits on rational grounds, several moral and ethical objections cause them to resent this instrument. Hence, of all interest groups, only the owners of firms are warm supporters of grandfathered tradable permits. All other interest groups prefer some form of direct regulation.

8.6 Assessment

The different motives for the interest groups discussed in Section 4 are not all taken into account in the public choice literature on preference for environmental policy instruments, which was summarized in section 8.5. More specifically, the motives of the interest groups are almost always equated with the motives of the owners and donors. Managers are virtually non-existent in this literature. In this section, we will assess whether taking all motives into account, including those of managers, as discussed in section 8.3, will change the preferences of the interest groups reviewed in section 8.5 and whether this will affect the outcome of the rent-seeking game. Furthermore, some other factors are discussed that may affect the choice of instrument and some suggestions for further research are given.

Politicians are not often taken into consideration when the choice of environmental policy instrument is analyzed. However, as discussed above, they will have certain preferences, which may alter the outcome of the analysis. Although they are not discussed often, all the motives mentioned in Section 4.1.1 are discussed in the literature on environmental instrument choice. Hence, we can conclude that politicians will mostly support direct regulation.

Most of the motives of bureaucrats as mentioned in Section 4.1.2 are also mentioned in the public choice literature on choice of instrument. A factor that has not received much attention is that environmental bureaucrats may have a preference for the output of their bureau, although it is implicit in Nentjes and Dijkstra (1994).

Casual evidence from the Netherlands (Volkskrant 1999) shows that environmental bureaucrats see themselves as the guardians of the environment, and not as the executors of ministerial decisions. Hence, the preferences of the environmental bureaucracy may resemble those of environmental organizations to a large degree. Whether this resemblance is a result of capture of the bureau by the environmental organizations, or of self-selection of environmental bureaucrats is not certain. As the discussion in the previous section about environmental organizations shows, this will not lead to a unanimous preference of policy instrument. However, it may be that the environmental bureaucrats share the moral and ethical objections against economic instruments. This would imply that environmental bureaucrats are mostly command expansionists, and therefore prefer direct regulation.

In the literature discussed above, the only objective of industry is to maximize profits. However, as we have seen in Section 4.2, this is the objective of the shareholders. Only a few authors mention this (e.g. Nentjes and Dijkstra 1994 and Dijkstra 1999). When doing so, however, they do not mention that there may be a conflict of interest between shareholders and management.

The question is whether the objectives of managers will change the preference for environmental policy instrument. This could be when managers have a preference for firm size, and more specifically for high levels of production. Section 4.2.2 showed that firm managers will have such preferences. However, it is highly implausible that such output preferences are absolute. The manager will have to find a compromise between the profit and output objectives. It can be modeled as a managerial utility function with profits and output as its components. It is also probable that for managers short run outcomes count for more than long run results.

As Dijkstra (1999) shows, relative standards will result in a higher level of production than all other instruments. In the short run then, when the number of firms does not change, or if there is no entry even in the long run, firm output will also be larger with relative standards than with any other instruments. Managers would then prefer this instruments. However, in the long run, with entry, Dijkstra (1999) shows that firm output is highest under taxes and tradable permits, although the number of firms is lower than with any other instrument. Managers may then prefer grandfathered tradable permits, which is in perfect alignment with the preferences of shareholders. However, the fact that market instruments leads to more exit of firms from the industry will dampen the enthusiasm of managers for these instruments. Therefore, which instrument managers prefer depends on the situation and on whether or not they expect entry in the industry.

It is, however, not certain that managers can lobby for their own preferences. If the influence of shareholders is large, managers will have to choose the profit-maximizing instrument, i.e. grandfathered tradable permits. If on the other hand, shareholders have little influence, managers will be able to push for relative standards. This may explain the apparent differences between the US and Europe in preference for instrument by industry. In the US, shareholder influence on management seems to be rather large. At the same time, US industry prefers grandfathered tradable permits. In Europe on the other hand, shareholder influence is not so large. As a consequence, managers are able to lobby for their preferred instrument.

The most used assumption about the objective of labor unions is that they maximize employment. Even though as we have seen above, labor unions are more interested in maximizing employment than in maximizing wages, high wages are an important factor in labor union preferences. Only Leidy and Hoekman (1994) mention that unions may prefer instruments which maximize profit, because the union hopes to capture part of the profits as higher wages. If we assume that employment is increasing with production and wages are increasing with profits, labor unions are put in a dilemma. Relative standards cause the highest production level, and thereby the highest level of employment. On the other hand, profits are highest with grandfathered tradable permits. Similar to firm managers, one could model labor unions as maximizing a utility function with aspired profit share and employment (with sector output as its indicator). Again, the union's choice would depend on its priorities and the differences in impact instruments have on union preferences. It is plausible that in times of high unemployment priorities and choices would differ from those in times of labor shortage.

As was mentioned in Section 4, the leadership of labor unions will have a preference for a large membership of their organizations. Since there is a positive relationship between employment and membership, the union leadership has an incentive to strive for maximum employment. Since most studies take employment maximization as the objective of labor unions, assuming that the leadership has an influence on the policy of the union will not change the outcome. However, it must be noted that the assumption that unions maximize employment is never based on the preferences of the union leadership.

The general assumption about environmental organizations in the public choice literature discussed above is that they are risk-averse and want to maximize environmental quality. Furthermore, they have an anti-economic instrument bias because of moral and ethical reasons. From this it is concluded that environmental organizations prefer direct regulation. The management of environmental organizations, on the other hand, prefers a large membership. One main way of achieving this is by providing environmental quality, i.e. by having success. To realize this, the management may be more willing to compromise with industry. Therefore, they may support grandfathered tradable permits. It should also be taken into account that within environmental organizations the anti-market sentiments seems to have lost in strength, similar to the development within the environmental bureaucracy.

A factor that is almost never mentioned in the literature is that governments provide a large part of the funding for non-profit organizations (Rose-Ackerman 1996). The possibility of receiving state funding may change the preferences of environmental organizations. State funding will most likely flow to environmental organizations that are willing to negotiate and compromise; those with extreme and uncompromising opinions will not easily attract state funding. There are two advantages of state funding for the management of environmental organizations. Firstly, it provides them with additional funding, which can be used to improve environmental quality, but also partly as discretionary spending by the management. Secondly, the government is less likely to hold the management accountable for the way the funds are spent than private donors are. Hence, state funds give a greater possibility for discretionary spending than private donations. For these reasons, the management of environmental organizations may be willing to compromise on some of their more extreme positions. A likely candidate is their resistance to tradable permits. Hence, we expect that the possibility of state funding will make the management of environmental organizations more willing to support tradable permits.

Taking into account the motives as discussed in Section 4 can make some difference to the analysis. The clearest alteration in preferences occurs within firms. When the motives of managers are taken to be dominant, instead of those of the owners, the preference of industry shifts from grandfathered tradable permits to relative standards. Hence, now even industry is opposed to market-based instruments. The result would be that all interest groups have a preference for some form of direct regulation, which could explain why market-based instruments are so little used.

Taking more motives into account with bureaucrats and labor unions does not alter the analysis dramatically. Environmental bureaucrats may share some of the moral objections to market-based instruments with environmental organizations. This will make them prefer direct regulation even more. In labor unions, the preference for higher wage by the members is not often taken into account. Such a preference would lead to a greater support for grandfathered tradable permits. However, the preference of the union leadership for a large membership counters this factor. In the end, labor unions are most likely to stress the effects on employment than on wages.

There are several gaps in the literature. One point is the cost savings that can be brought about by emissions trading. In many studies, the cost savings of emissions trading, even in less than perfect forms, are given to be in the range of 20 to 60 % (Klaassen 1996; Boom et al. 1998; Schmalensee et al. 1998). To industry, costs of environmental regulation are one of the most important factors to object it. Hence, they should embrace emissions trading when regulation is inevitable. Furthermore, the costs saving, together with the rents given to shareholders when permits are grandfathered, should make it possible to compensate other groups that resist emissions trading. With emissions trading, environmental policy can be stricter, while still leading to lower costs to industry. Lower emissions are in the interest of both the environmental bureaucracy and environmental organizations. Hence, they should also be supporters of emissions trading.

A shift in attitude towards tradable permits is therefore also visible. Other factors also work in favor of the implementation of grandfathered tradable permits. There is a general decline in the anti-market sentiment.

This affects the attitudes of environmental organizations, the environmental bureaucracy and politicians. Furthermore, experience with SO_2 permit trading in the USA has shown that this is a very effective and efficient instrument. Earlier forms of emissions trading in the USA had already shown that large cost improvements could be gained from emissions trading. However, these schemes were often rather cumbersome and overtly bureaucratic. The SO_2 scheme in the US and the recently introduced CO_2 emissions trading scheme in the EU are however much better designed and are projected to lead to high cost savings. The introduction of the CO_2 trading scheme in the EU has also forced Member States to change their legislation to make such trade legally feasible. This should open the door to the use of grandfathered tradable permits in other fields too.

Many analyses include direct regulation, but often it is not specified which type of direct regulation is meant. This is a problem since the different forms of direct regulation have a rather different impact on the regulated industry. In many cases, direct regulation is taken to be synonymous with emission ceilings. However, this is not an often used instrument in practice. Here, voluntary agreements, technological standards and relative standards are the most popular instruments.

Especially problematic is the lack of interest in voluntary agreements. As we mentioned, voluntary agreements can be seen as a type of direct regulation since they specify the tasks for the involved sources, often in the form of relative standards. But there are also some important differences with direct regulation in general. In the first place, the exchange of information between bureaucrats and firm representatives and between the latter themselves make it possible to differentiate standards between firms on the on the basis of differences in abatement costs, whereas with conventional regulation standards tend to rather uniform. Therefore, voluntary agreements deliver cost savings compared to direct regulation, which makes them more efficient. Next to that, enforcement of compliance is more complicated than with direct regulation. Firms therefore could strategically use voluntary agreements to delay full compliance. Furthermore, the negotiations with the regulating agency brings firms in a position where they can try to bring down the total emission reduction proposed by the environmental bureaucracy. All three characteristics, which distinguish standard setting under voluntary agreements from standards under regulation, make that industry will prefer voluntary agreements over direct regulation through relative standards.

Another instrument not often discussed is credit trading. Here, the industry is regulated through relative standards. These standards are often rather uniform, so that marginal abatement costs may vary between firms. However firms are allowed to sell emission reduction credits when they can stay below the emission target defined by the standard. Other firms can buy credits so that they can emit more than the standard. This introduces flexibility in several ways. Because of the relative standard, firms can increase emissions when they want to increase output. Furthermore, marginal abatement costs can be equalized between firms. Firms should prefer credit trading to regulation through relative standards because of the added flexibility.

As mentioned, credit trading requires uniform relative standards in order to keep administrative costs, including monitoring and enforcement costs, low and credit trade transparent. The Dutch NO_x credit trading program is a good illustration. Consequently, voluntary agreements with their differentiated standards are not a good basis for credit trading. Therefore, it makes sense to see voluntary agreements and credit trading as alternatives for making direct regulation through relative standards more flexible. Both alternatives bring cost savings but with credit trading these are highest since it makes equalization of marginal abatement costs possible. With voluntary agreements this will only be the case if firms have identical abatement cost functions.

Besides industry, other interest organizations also support voluntary agreements and credit trading. The lower costs mean that output can stay higher, implying higher employment in the industry, so that labor unions will favor these two instruments. The lower compliance costs also make it easier for industry to comply with the national emission target, which is in the interest of the environmental bureaucracy. Furthermore, the cost savings may make it possible to induce industry to abate more. This would be in the interest of both the environmental bureaucracy and environmental organizations. Voluntary agreements also require large input of bureaucratic labor in the negotiation phase and in monitoring and enforcement. Furthermore, they give the bureaucracy a certain level of control with the industry.

Based on the overview of the literature and our assessment, we present the following preferences of the different interest groups, summarized in Table 8.1. Industry will have a preference for voluntary agreements or credit trading, especially when the interest of managers dominates shareholders' interests. In the reverse case, industry will prefer auctioned tradable permits since this gives the highest rents to shareholders. Labor unions will prefer credit trading since these give the highest level of output. They will also support voluntary agreements, especially when these specify differentiated relative standards for individual firms. Environmental organizations prefer tradable permits, since this gives them a high certainty that the overall target is realized and makes it possible to set a more stringent policy because of the costs saving to industry. However, environmental organizations will prefer permits to be auctioned, so that the right to pollute is not given away for free. The environmental bureaucracy will prefer voluntary agreements because they give lower compliance costs which should result in better compliance. Furthermore they give the bureaucracy a measure of control with industry and require high input of bureaucratic labor. Next is credit trading because this also gives lower costs to industry and is not a large departure from current policy. Finally, command minimalists within the bureaucracy may prefer grandfathered tradable permits because they give a high certainty of achieving the emission target, while leaving the industry free in the choice of abatement method.

8.7 Conclusions

To understand why certain policy instruments are implemented and others not, insight is needed into the motivations of the agents involved. First of all, the actors that are involved in the process of policy making need

Table 8.1: Preferences of Interest Groups

	Industry	Labor Unions	Environmental organizations	Environmental bureaucracy
1	Voluntary agreements	Credit trading	Auctioned permits	Voluntary agreements
2	Credit trading	Voluntary agreements		Credit trading
3	Grandfathered tradable permits			Grandfathered tradable permit

to be properly defined. In all instances, managers play an important role. They steer the organization and they lobby for a certain instrument. The preferences of the owners or donors of the organization are important. But these should not be equated with the preferences of the organizations. In all organizations, the managers will have opportunities to act at least partly so as to fulfill their own objectives.

The public choice literature on environmental policy instrument choice most often does not take this aspect into account. This is most problematic in the analysis of firms. Shareholders will want the firm to maximize profits. The instrument that does this is a system of grandfathered tradable permits. The managers of the firm, however, also have a preference for a large scale of production. They may therefore lobby for relative standards, which allow the largest production level. In other organizations, the preferences of managers do matter, but do not always have a decisive influence on the preference for instrument. The preference of managers for relative standards can partly explain why market-based instruments are seldom used. Not only the regulator, but also the regulated party, opposes such instruments.

Also, other aspects are sometimes forgotten. Workers will prefer both high employment and high wages. The literature on instrument choice however, almost unanimously connects labor unions with the goal of maximizing employment. Environmental organizations may compromise on their moral objections to tradable permits to receive state funding and to achieve success in supplying environmental quality.

Taking the motivations of managers into account does not in general lead to more unequivocal results. When politicians are allowed to have an ideology, the group falls apart in two sub-groups: those that want to reduce government control over firms and those that want to expand it. The same division is apparent in the environmental bureaucracy. In explaining the outcome of environmental policy, one should therefore investigate which of the two groups was dominant within both politics and the environmental bureaucracy.

This is not to say that the literature on the choice of environmental policy instrument so far has not made any contribution to explaining the dominance of direct regulation. It shows that most organizations have a preference for direct regulation, although for different reasons. The literature is rather unanimous in its conclusion that the dominance of direct regulation, specifically the practice of setting relative standards, can be explained by the support it has from about all major interest groups. The literature even suggests that other instruments hardly have a chance of being introduced.

However, one sees change and perhaps even the beginning of the rise of market instruments. These facts point to a weakness in the literature: interest group preferences for instruments are ranked and those rankings are presented as if they are absolute, neglecting the fact that losses from accepting a less preferred instrument could be compensated. In particular, it is overlooked that grandfathered permits, compared to direct regulation, often promise huge savings in abatement costs, exceeding the rather modest increase in administrative costs. Cost savings from 30 to 50% are no exception. Next to that, grandfathered tradable permits promise additional wealth to capital owners. Together, the cost savings and the wealth transfer to capital owners constitute a rent that can be used to compensate interest groups for the loss of accepting grandfathered tradable permits and sacrificing their favorite instrument. In the US, the sulfur allowance program for power stations could be introduced instead of the originally planned system of stringent SO_2 emission standards. The deal made here was more emission reduction than in the original program to satisfy environmental organizations while abatement costs were still lower for industry. At the same time, regions where negative employment impacts in mines winning high sulfur coal could be expected received large compensations. In the end almost all parties accepted the permit program and the law introducing the scheme passed Congress and the Senate with almost unanimous support. It seems astonishing that economists who have stressed the efficiency of market instruments from the beginning have been blind for the potential the rent thus created offers to negotiate a political solution to make these instruments acceptable to all major interest groups.

A further gap in the literature is its neglect of credit trading. Credit trading basically is a scheme of relative standards made flexible by allowing trade between sources with emission above and below the level defined by the standard. It promises industry savings in abatement costs, similar to permit trading, without the limits on total emissions set by the permit scheme. Evidently, industry will prefer relative standards with the flexibility of credit trading above emission standards without trade. The same holds true for labor unions. The rent created by the cost savings also offers scope for compensating the loss of environmental organizations and the environmental bureaucracy, which may be suspicious of allowance trade in pollution. Compensation could take the form of more stringent relative standards while leaving sufficiently lower abatement costs compared to direct regulation without credit trade. These considerations suggest that credit trading can expect broad political support of interest groups in all those domains where it is feasible and promises considerable cost savings.

Another gap in the literature is the scant attention given to voluntary agreements. With voluntary agreements, the emission target for the sector under consideration is negotiated between the sector and the government. Thereafter, firms within the sector can negotiate how to distribute the overall target over the individual firms. This often leads to considerable cost savings to industry compared to standards that are set by the environmental agency, even when the overall target is identical in the two cases. Considering the advantages of voluntary agreements for industry, it may even be preferred to credit trading. To illustrate this point, it should be mentioned that in the Netherlands thinking about and preparation of credit trading for NO_x emissions only started after prolonged efforts to conclude a covenant, which failed. The bottleneck was that the firms to be regulated were too many and too heterogeneous to strike a deal on differentiated standards. Voluntary agreements also ask for high labor input for negotiations, monitoring and enforcement. This may make it an attractive option for the environmental bureaucracy. It also scores on two other dimensions cared for by environmental bureaucrats: lowering abatement costs and keeping control over the industry. Consequently, industry as well as the environmental bureaucracy may prefer voluntary agreements as a way to make regulation more flexible. The conclusion is that voluntary agreements compete with credit trading and may develop side by side in the future to overcome the traditional inflexibility of direct regulation.

Chapter 9

Interest Group Preference for an International Emissions Trading Scheme

9.1 Introduction

To reduce the overall costs of committing to the national abatement obligations the Kyoto Protocol contains three flexibility instruments: Joint Implementation (JI) (Art. 6), the Clean Development Mechanism (CDM) (Art. 12) and International Emissions Trading (IET) (article 17). JI and CDM are both project-based instruments, where a baseline of emissions has to be estimated per project and emission reductions are measured against this baseline. The main difference between JI and CDM is that JI can only take place between Annex B countries which have committed to an emission ceiling in the period 2008-12, while with CDM the host country is a non-Annex B country. IET can only take place between Annex B countries and amounts to a transfer of greenhouse gas quotas between countries.

The basic design of JI and CDM is rather clear, however the Kyoto Protocol does not specify how international emissions trading should be conducted. Basically, there are three possible schemes of international emissions trading: government trading, permit trading and credit trading.

The description of emissions trading in Article 17 of the Kyoto Protocol clearly refers to trade between governments, although private trading has not been dismissed. In the case of government trading, trading can be seen as a bilateral renegotiation of the abatement commitments of the trading countries. After the trade is concluded, the countries involved will have to change the stringency of domestic policies to comply with their new commitment. It will be clear that government trading does not require a specific domestic instrument. Hence, government trading is compatible with any instrument applied at the national level.

Permit trading and credit trading are both private trading schemes. This means that under both schemes, individual emission sources will be able to trade directly with each other. International permit trading means that emissions sources are regulated through a system of tradable permits at the national level. International permit trading can then be conducted by linking the national trading schemes. With credit trading, the sources are regulated at the national level through some other instrument, most likely a relative standard, and sources that perform better than the standard can sell emission reduction credits to sources with emissions above the the standard set.

With joint implementation and CDM, it is not necessary that domestic policy has been implemented. Both instruments are based on emission reduction projects where for each project an estimate is made about the expected emissions in a business as usual scenario over the projects period. The project will then deliver emission reduction credits if real emissions are below business as usual emissions. Since the credits created by JI and CDM represent a certain amount of emission reductions, they can be traded on an international emissions market just as the permits and credits created through permit and credit trading. This then makes it possible to connect countries to the international emissions market even when they are not linked to such a market though a national permit or credit trading scheme.

The emissions trading schemes mentioned above have different characteristics; they have a different impact on factors such as profits, environmental effectiveness, compatibility with domestic instruments etc. For a review of the literature on this subject, the reader is referred to chapter 3. Because of the difference in characteristics between schemes, it is likely that different interest groups will have different preferences, and will be willing to sacrifice resources to ensure that their most preferred instrument is implemented. One has to note though that what is traded on the international emissions market are emission reductions. It does not matter whether these are credits, permits, Assigned Amount Units (AAUs) from government trading, or emission reduction units from JI or CDM. What matters is the manner in which domestic industry is regulated and subsequently connected to the international emissions market.

In this chapter, we present both a theoretical analysis and empirical evidence of the preferences of interest groups for an international emissions trading scheme and building on the results of chapter 8 on preferences for national instrument. We analyze the preferences of industry, labor unions, environmental organizations and the environmental bureaucracy in the theoretical part of the chapter. However, in the empirical part, we only discuss industry and environmental organizations. The reason for this is that these two groups are most visible.

Since there are no surveys available on the preference of interest groups for an international trading regime, we have chosen to gather information on the Internet. This was done in the year 2000, which is why newer information is not taken into account. Because interest groups are also interested in the support of the general public, we expected that they would provide information on their opinions on this medium. In general this was right, although environmental organizations use the Internet more as a platform for distributing information than industry does.

Gathering information in this way may cause some problems. The organizations that present themselves on the Internet may only be a selection of the total number of organizations involved. Although this may be true, it is also an advantage. Only organizations that have formed an opinion and want to influence policy makers and public opinion are present on the Internet. Other groups may be affected, but as long as they do not form an opinion themselves, they will not affect the decision making process and are therefore irrelevant to this study.

Three problems arise when analyzing interest group preferences for an international emissions trading scheme. First of all, there is an interdependence between the choice of national instrument and the choice of international trading scheme. International permit trading is, in essence, an international linkage of national tradable permit schemes. Hence tradable permit schemes are a prerequisite for international permit trading. Similarly, national credit trading is a prerequisite for international credit trading. On the other hand, government trading and JI can be combined with any national instrument. The consequence of this is that if an interest group prefers permit or credit trading at the national level, it cannot logically choose another trading scheme at the international level. The preferences for national instrument by the different interest groups has been discussed in chapter 8. In this chapter, we take the conclusions from chapter 8 as a starting point for our analysis on preferences for international trading scheme.

A second problem is the existence of 'hot air'. By 'hot air' we mean that some countries have received a higher emission ceiling in the Kyoto Protocol than their real emissions will be. These countries can therefore sell emission quotas without reducing emissions. Although this in itself is seen as a problem by some, it also expands the discussion on the choice of international trading scheme. If one can stop the trade in hot air, total emissions will be lower than with hot air trading. Since the three trading schemes and JI give different opportunities to limit the trade in hot air, the preference of trading scheme now becomes dependent on the preference for emission level.

The third problem is that some groups have the view that Parties to the Kyoto Protocol should do their utmost to achieve the emission target in the Kyoto Protocol solely through domestic measures. Several arguments for this are mentioned. The most important one is that it adds pressure on politicians and industry to invest in research and development leading to new, low-cost abatement options. This would set the stage for further emission reductions in a next commitment period after the first period from 2008 to 2012. Groups adhering to this view would rather have no international emissions trading at all. Seeing that this is not possible, since the Kyoto Protocol already allows it, they would like to limit trade in emissions as much as possible. In this respect, they are even more radical than the groups that want to eliminate hot air (although there is a certain overlap between these groups). Similar to both is that their resentment of international emissions trading will affect their preference for the three types of international emissions trading.

The remainder of this chapter is organized as follows. The theoretical analysis of interest group preferences is given in section 9.2 and the empirical evidence is discussed in section 9.3. Finally, in section 9.4 we give some conclusions.

9.2 Interest Group Preferences: Theory

In this section, we will give an analysis of the preferences of interest groups for an international emissions trading scheme. The three possible schemes are permit trading, credit trading and government trading. Furthermore, we will discuss the position of the interest groups with respect to limits on trading.

Industry In chapter 8, we concluded that industry's first preference for national instrument is voluntary agreements. Industry's second and third choice are credit and permit trading.

As we have seen in chapter 8, voluntary agreements are high in the preference ranking of industry. This instrument is more flexible than uniform performance standards or emission ceilings and will help to lower abatement costs. However, when voluntary agreements (or direct regulation) are implemented at the national level, the national market institutions for international permit or credit trading are lacking. The only instruments for international emissions trading that remain are government trading and joint implementation. The question then is whether it is in the interest of industry to have government trading as a complement to national voluntary agreements. The answer to that question depends on whether the country is a seller or buyer of emission quotas. By buying emission quotas on the international market, there is scope to relax the emission targets for voluntary agreements and direct regulation. In this case industry will support government trading since this will lead to lower costs for industry. In case the country is a potential seller, industry will not always support government trading. Much depends on who receives the proceeds of trading. Industry will argue that since they deliver the emission reductions that back the sale of emissions, they also have a right to the profits from the trade. If industry receives the full proceeds from trading, it will back government trading. However, if it does not, and receives less than its costs (or even nothing), industry will oppose government trading vehemently.

National relative standards or national credit trading are second (or perhaps first) in the ranking of industry's preferences. If credit trading is implemented nationally, firms can easily be connected to the international emissions market. The question is again whether or not this is in the interest of industry. Suppose that marginal abatement cost functions of industry are uniform and that the emission quota price on the international market is higher (lower) than the credit price on the national market. In that case all firms will be sellers (buyers) on the international emission quota market and will have benefits from international trade, either through higher revenues or through lower costs. Industry will thus support international emissions trading unanimously without any restrictions. However, unanimity will disappear if marginal abatement costs differ between firms. Now low-cost firms are sellers and high-cost firms are buyers on the national market. If the international quota price is above the national credit price, international trade is unequivocally in the interest of firms that will become sellers on the international market. However, for firms that already were buyers on the national market and that will still be buyers on the international market costs will increase and hence they will lose from the shift to international emissions trading. But it will normally be such that some firms that are buyers on the national market will become sellers on the international market when the international price is above the national one. It is not immediately clear whether these firms will gain or lose from international emissions trading. If the international price is below the national price, the reverse will be the case. Therefore, there will only be unanimous support for international emissions trading when all firms become either sellers or buyers on the international market. That will be the case if the international quota price diverges enough from the national credit price. If this is not the case, the position of industry as a group depends on the gains or losses of the dominant subgroups within industry.

Industry may also prefer a national grandfathered permit trading scheme if shareholders' interest in high profits dominates managers' preferences and decisions. Also a national permit trading scheme can easily be connected to an international emissions trading market. Whether industry prefers international emissions trading again depends on the relation between the national and international permit price. Suppose that potential buyers of quotas dominate the industry lobby and that the international quota price is below the national price. International emissions trading will then lower the total costs of abatement and permit expenditure for buyers of quotas, similar to the case of credits. However in this case firms have received permits for free and the value of the grandfathered permits are a rent to shareholders. The lower international price of permits then also lowers the rent reflected in the value of shareholders' stock. This means that now there is a trade-off between the direct loss for shareholders and improved prospects for the firm due to lower costs of output. The latter may give short run profits, but more importantly will increase the likelihood that the firm will survive, especially if it operates on an international output market where some of its competitors are not regulated. In this case, a prediction about the firm's preference cannot be made. Whether it is in favor of international emissions trading depends on the impact of the two effects. In Table 9.1 four possible cases are given. Only for firms that are sellers both on the national and the international market an unambiguous assessment of preference can be made. These firms are against international emissions trading when the international emissions price is lower and are in favor when the international emissions price is higher than the domestic permit price. For all other cases, the outcome is ambiguous.

Table 9.1: Impact of a shift to international emissions trading on permit rent and firm costs

Position of industry	International price compared to national price			
	lower		higher	
Buyer	rent lower	$-$	rent higher	$+$
	cost lower	$+$	cost higher	$-$
Seller	rent lower	$-$	rent higher	$+$
	cost higher	$-$	cost lower	$+$

Support for private emissions trading, be it credit or permit trading, does not prevent industry from supporting government trading at the same time. If the government buys emission quotas in the international market, there is room to relax the stringency of national environmental policy. As long as the additional emissions are handed out for free to industry, this would be a gain to them. For credit trading it would imply more lenient relative standards, while for grandfathered tradable permits it would mean a larger initial distribution of permits. In all cases, abatement costs would be lower for industry. For permit trading, it could mean a larger rent to shareholders if firms are allowed to trade internationally. If not, the domestic price of permits would decrease as a result of the higher total ceiling on emissions, which would counteract the larger distribution of permits to industry. Industry would however oppose government trading if this implies sale of emission quotas that are backed by more stringent environmental policy toward industry.

The conclusions of the analysis of industry preferences for international emissions trading scheme are summarized in table 9.2. It appears that support for international emissions trading depends on whether the industry is a seller or buyer of quotas in the international emissions market in the case of voluntary agreements or direct regulation; on being a seller or buyer and on the international emissions price compared to the national credit price in case of national credit trading; and with permit trading both these and the impact on the rents to the shareholders. It turns out that it is far from clear which instrument of international emissions trading industry prefers and their support for international flexibility instruments is far less than for national flexibility instruments. Furthermore, it is easier to determine whether industry supports international emissions trading the less sophisticated the national instrument is. For example if industry is a buyer of emissions quotas on the international market, they will support international trade when voluntary agreements are the national instrument. If the national instrument is credit trading, industry will support international trade in this case when next to being a buyer, the international quota price is below the national credit price. With permit trading as national instrument it is hard to say when industry will support international emissions trading when it is in a position of being a buyer.

Labor unions The discussion on labor unions in chapter 8 showed that their prime concern is employment. Assuming that employment is closely related to output, labor unions should have a preference for instruments that lead to the lowest decrease in output possible when environmental policy is implemented. Their first preference therefore is credit trading or relative standards. However, they will also support voluntary agreements, especially if these set relative standards for the individual firm.

For international emissions trading this implies that private trading is possible if credit trading were implemented at the national level, otherwise government trading and JI are possible. Whether labor unions support international emissions trading depends on whether the international emissions quota price is lower than the domestic credit price (or whether the government buys quotas). In that case, connection to the international emissions market will mean that the regulated industry can reduce marginal costs and expand production. On the other hand, a higher price than the domestic one implies that marginal costs will rise and production will go down.

Hence, labor unions will support international emissions trading when the international emissions quota price is below the national credit price. If this case labor unions will reject a cap on trading; after all, such a cap will increase the cost of compliance for industry and thereby lower production.

Environmental organizations The main objective of environmental organizations is to reduce pollution as much as possible. If there are any targets, they must be met with as much certainty as possible. Only emission ceilings and tradable permits give certainty about the attainment of the target and should therefore be the preferred instruments of environmental organizations. Although traditionally environmental organizations have had reservations about the use of tradable permits, lately they have been more positive about this instrument. As we mentioned in the previous chapter, with grandfathered tradable permits it is possible to abate more while at the same time lowering costs relative to traditional command and control types of regulation. Hence industry is willing to accept more stringent targets with tradable permits than with direct regulation which is exactly what environmental organizations want. However, different from industry, environmental organizations prefer the permits to be auctioned instead of grandfathered so that the right to pollute is not given away for free.

Some countries have received hot air under the Kyoto Protocol. This means that these countries can sell emission quotas without having to reduce emissions. Hence, if the trade in hot air could be banned, total emissions would be lower. For this reason environmental organizations may resist international emissions trading in any of the three forms.

Besides the hot air argument, environmental organizations have a second argument against international emissions trading. Restricting trade will force industry to invest more in research and development of abatement technology, making abatement cheaper. This would create more favorable conditions for future negotiations on emission reductions (Woerdman 2002, ch. 8).

A third reason to distrust international emissions trading is the fear that it will deteriorate compliance of Annex B countries to the Protocol. For example, if seller countries cannot be relied on to reduce their emissions in accordance with their quota sales, and buyer countries see purchased quotas as a legitimization to increase emissions, the prospects to realize the overall emission reduction target set in the Protocol will deteriorate. This concern also spawned the discussion on whether sellers or buyers should be liable for noncompliance by sellers of emission quotas (see Woerdman (2002, pp. 148-154) for an overview).

The consequence of these considerations is that if international trading cannot be prevented, environmental organizations at least want a cap to be imposed on the amount of permits bought abroad. This could at least limit the negative environmental impacts that environmental organizations expect from international emissions trading. Such a cap is however not easily administered under permit and credit trading. If industry is only allowed to purchase say 50% of their target abroad, does this then apply to every individual firm or to industry as a whole? In the latter case, which firms are allowed to trade? Furthermore, it may not be immediately clear whether emission quotas bought are foreign or domestic. Hence, a cap on trading can only work properly in the case of government trading. There are of course other possibilities to limit international emissions trading. One could for example limit trading to countries that do not have hot air and/or that have a strong monitoring and enforcement policy. Also these limitations to trading are most easily implemented in a government trading scheme.

We therefore expect that environmental organizations will oppose international emissions trading, both in the form of private and government trading, even though they do accept national permit trading. If international emissions trading is inevitable, environmental organizations will prefer government trading since it then is possible to limit emissions trading in several ways.

Environmental bureaucrats The bureaucracy has several motives. Bureaucrats will be risk-averse, prefer a large bureau, resist new methods, minimize resistance to their decisions and may have a preference for the output of the bureau, that is they want to realize the national emission target. Furthermore, they are split into command minimalists and command expansionists.

As we saw in chapter 8, the environmental bureaucracy is divided over the choice of national instrument. The bureaucracy may have a preference for voluntary agreements since these provide flexibility to industry but still give the bureaucracy a measure of control with the industry and they require high bureaucratic labor input for the negotiations with industry. On the other hand, relative standards are an already much used instrument. These could relatively easily be made flexible by allowing credit trading. However, a part of the environmental bureaucracy wants less control with industry and may therefore prefer permit trading.

Whether environmental bureaucrats support international emissions trading depends on whether the country will become a seller or a buyer of emission quotas in the international market. The less domestic industry has to reduce emissions, the easier it is to attain the target. Therefore, bureaucrats will support international emissions trading when the country is a buyer. Selling permits is equivalent to more stringent environmental policy, which will be harder to realize by industry. Bureaucrats will therefore not support international emissions trading when the country becomes a seller.

Which form of international emissions trading scheme the environmental bureaucracy will prefer depends partly on their preference for national instruments. If voluntary agreements are implemented, only government trading and JI are possible flexibility instruments, while if credit or permit trading are implemented, both private and government trading are possible. The question however is which scheme environmental bureaucrats prefer. If industry would be a buyer of emission quotas internationally, the bureaucracy should be in favor of international private trading since this will make it easier for industry to comply with the national target. But the environmental bureaucracy may reject unfettered private trading.

One reason is that bureaucrats share with environmental organizations a concern that international emissions trading will deteriorate the environmental effectiveness of the Kyoto Protocol. Hot air will be seen as a problem as well as possible non-compliance by sellers of emission quotas. Furthermore, the environmental bureaucracy will demand a certain minimum abatement effort from domestic industry. This will increase the bureaucrats' control with the industry and lead to more national innovation in abatement technology. These arguments all lead to a preference to restrict international trade in emissions in certain ways. One possibility is to place a cap on trading. This will lead to a certified level of domestic action, as wanted by the bureaucrats. However, it does as such not prevent trade in hot air. To achieve this, bureaucrats could push for government trading, which gives them full control over who the trading parties are and how much is traded. Another possibility is to ban trade with hot air countries and countries that do not have an effective emission monitoring and enforcement policy.

The conclusions for the environmental bureaucracy are presented in Table 9.2. The bureaucracy will support international emissions trading when the country is a buyer of emission quotas since this will increase the possibilities of compliance with the Kyoto commitment. However, it does not support unfettered trade, but would like some limit both on how much is bought abroad and who to buy from. Here, the bureaucracy would like to restrict trade with hot air countries and with countries without proper control and enforcement policies. Limiting trade in this way can most easily be achieved by only allowing government trading. If private trading is unavoidable, there should at least be a ban on trade with hot air countries and those with ineffective enforcement policies.

Whether interest groups support international emissions trading depends highly on the position of domestic industry vis a vis the international emission quota market. If the industry becomes a buyer in the international market this will lower costs, increase output and make it easier to comply with the national Kyoto commitment. On these grounds, industry, labor unions and the environmental bureaucracy will support international emissions trading when the country becomes a buyer of quotas. If on the other hand the country becomes a seller, labor unions and the environmental bureaucracy will not favor international emissions trading, while industry may still favor it as long as it can profit from it. Only environmental organizations resist international emissions trading in all cases.

Another result is that there is much support for government trading, although for different reasons. Industry hopes that emission quotas bought

Table 9.2: Preferences of interest groups

	National instrument	International trade	Trade limits	International instrument
Industry	VA	yes or no	no	gov. trade; JI
	credit trading	yes or no	no	private and gov.
	gr. permit trading	yes or no	no	private and gov.
Labor Unions	credit trading	yes or no	no	private
	VA	yes or no	no	gov. trad.; JI
Env. org.	Auct. permits	no	yes	gov. trad.; JI
Bureaucracy	VA	yes or no	yes	gov. trade; JI
	credit trading	yes or no	yes	gov. and private
	gr. permit trading	yes or no	yes	gov. and private

Note: gr. = grandfathered, gov.= government trading

by the government abroad will be distributed to them for free, thus lowering compliance costs. For the environmental bureaucracy and environmental organizations, government trading gives most control with how much is traded and who is traded with.

Since limits on trading increase the costs of compliance, industry and labor unions will reject them. Environmental organizations and the environmental bureaucracy, on the other hand, will support them. Their reasons are that limits to trading can diminish the use of hot air and trade with countries without effective monitoring and control. Furthermore, limits on trading make that domestic industry has to make an effort to reduce national emissions, leading to more research and development of abatement technologies.

9.3 Interest Group Preferences: Empirical Evidence

In this section we present empirical evidence on the preferences of interest groups for both a national instrument and an international emissions trading scheme. To gather the information, we used the Internet. Interest groups will try to influence public opinion by arguing their case in public. Therefore, we expected that interest groups would also provide information on their opinions on the Internet. In general this was true, although we were not able to find information on all groups. More precisely, we only found information on industrial and environmental organizations.

Environmental bureaucrats have no interest groups that voice their preferences publicly. Hence, we could not find information on their preferences. Labor unions do not seem to be very involved in the debate on international emissions trading and hardly any information on their preferences could be found on the Internet. Therefore, we excluded them from the empirical analysis. The research for this section was done in the year 2000 and reflects viewpoints of interest groups at that time.

9.3.1 Industry

National instrument Most industrial organizations express a preference for voluntary agreements. This is the case for the three global organizations we found information on. Also, US industrial organizations express a preference for voluntary agreements, which is perhaps rather surprising when one considers their warm support for tradable permits in the case of SO_2 abatement (Svendsen 1998a. Noting the history of environmental policy in Canada, Japan and Europe, the support for voluntary agreements in these countries is less surprising. There is, however, also some support for market-based instruments, especially grandfathered tradable permits. Such support is found in the UK, Norway, Denmark, New Zealand, Australia, and partly in other countries.

Several reasons are given by industry for its preference for voluntary agreements. In the first place, as stated by the Edison Electricity Institute, 'the best way to address climate change should be voluntary, cost-effective and flexible' (EEI et al. 1998). In general, industry sees voluntary agreements as cost-effective and flexible (Toyoda et al. 1997 ; CEFIC 1998). With flexibility, industry means two things. In voluntary agreements, industry negotiates certain abatement goals with the government. How these goals are met is left to industry to determine. Hence, voluntary agreements give industry a free choice of how to reduce emissions (Meller and Hildebrand 1998). By doing so, they allow for differentiation of emission reduction targets according to firms' capabilities, thus reducing abatement costs for the group of participants in the voluntary agreement. Most of the time, voluntary agreements specify a relative target. In the case of CO_2 emission reduction, the target is often to improve energy efficiency. This is, for example, the case in the agreement between industry and the government in the Netherlands, in which industry commits itself to be in the top 10 per cent efficient firms within their sector (VNO-NCW 1999a,b). This kind of agreements allows industry to increase total emissions when production is increased, although they have to reduce emissions per unit of production. Thus, industry also wants flexibility in the total level of emissions (Business Roundtable (BRT) 1997 and EPSA 1998).

Another reason for supporting voluntary agreements is that they give industry influence over the environmental bureaucracy and politicians. Industry is surprisingly frank on this issue. It is, for example, said that industry should participate in voluntary agreements, because doing nothing would 'diminish electric utility influence on regulators, possibly subjecting companies to government control that tell them what strategies and technologies to use' (Kinsman et al. 1996). Furthermore, voluntary agreements improve 'the dialogue between those who set environmental objectives and the economic actors' (UNIPEDE and EURELECTRIC 1999b).

Industry does not support the use of taxes to reduce greenhouse gas emissions. It should be noted here that only the European industry voices opposition to taxes. Whereas American industry has been able to avoid environmental taxes to a large extent, European industry is regulated partly through taxes and charges although these are never set at a level reflecting marginal damage to society, but act more as a device to collect taxes earmarked for environmental projects (Stavins 2000). American industry, therefore, concludes that taxes are not an option in the control of greenhouse gases, while European industry feels that these might be used. The main reason for resisting taxes seems to be that industry is of the opinion that taxes deprive industry of the funds needed to invest in abatement technology (European Chemical Industry Council (CEFIC) 1997, 1998b and Meller and Hildebrand 1998). It is also argued that taxes are far less effective than voluntary agreements (Meller and Hildebrand 1998). Finally, taxes increase the already high costs of energy in Europe (VBO-FEB 1998).

Emission ceilings per firm are rejected as well. According to industry, they are 'tantamount to rationing use of fossil fuels and would thereby entail unacceptable limitations on production' (European Chemical Industry Council 1998a). Furthermore, absolute emission caps 'could severely threaten industrial competitiveness, employment and growth' (IFIEC 1998).

The support for voluntary agreements is also shown in the large number of agreements already in existence. The Canadian Pulp and Paper Association (CPPA) and the Canadian Electricity Association (CEA) support the Voluntary Challenge and Registry (VCR) Program, a voluntary program to reduce greenhouse gas emissions (Weyerhaeuser Jr. 1996, CEA 1996). Dutch industry has likewise made an agreement with the government (VNO-NCW (999a,b). Voluntary agreements also exist in Australia.

Although voluntary agreements are preferred by the largest number of industrial organizations, there is also some support for (grandfathered) tradable permits. The support is concentrated in Australia, New Zealand, the UK and Scandinavia, but some organizations in other countries also support tradable permits. The main reason for preferring them is their cost-reducing potential (Business Roundtable (BRT) 1999, Confederation of British Industry (CBI) 1999a,b and NZBR 1996, 1999). Furthermore, tradable permits will reflect the environmental costs in the energy prices (Næringslivets Hovedorganisasjon 1998, 1999) and 'such instruments make sustainable energy more competitive and will move the innovation process in an optimal direction' (Metz 1998). Finally, there is an expectation that private international emissions trading will be allowed. In that case, industry can prepare for this by setting up a national tradable permit system. This seems to be one of the reasons why the Confederation of British Industry (CBI) has designed an industry-wide scheme for emissions trading in cooperation with the British government (CBI 1999a,b). The CBI states that 'The aim of the emissions trading project is to design a scheme for emissions trading in the UK which could then link into a future international emissions trading scheme' (CBI 1999a). Furthermore, it is hoped that the scheme will keep the UK in the 'vanguard of international emissions trading and in a good position to get involved in any future schemes' (CBI 1999b).

However, some objections to tradable permits have also been voiced. For example, the National Association of Manufacturers (NAM) thinks that tradable permits would place a disproportionately large share of the abatement burden on industry. Furthermore, such a scheme would put small manufacturers at a disadvantage (NAM 1999). There is also doubt about the instrument because of the limited experience with it (Fay 1999).

Does the empirical evidence support the theoretical analysis? Above, we concluded that industry's preference ordering was voluntary agreements, credit trading and permit trading. The empirical evidence shows that voluntary agreements are the preferred instrument of most industry organizations, at least in the case of greenhouse gases, so that we have a confirmation of theory on this point. Furthermore, as industrial organizations often mention themselves, the voluntary agreements almost always contain some relative target. Thereby, they are closely related to relative standards as an instrument where the level of the standard is set through negotiations between industry and the government.

However, in some countries, permit trading is preferred to voluntary agreements. This holds for the UK, Norway, Denmark, Australia and partly New Zealand and Sweden. The reasons for this preference can vary between countries. For some countries, it is expected that they will gain much from international emissions trading. These are the high- and low-cost countries. Norway and Sweden are high-cost countries. They rely on hydro power for a large part of their power generation. Sweden has also decided to phase out its nuclear power stations. These countries will presumably rely heavily on emissions trading to comply with their abatement commitment under the Kyoto Protocol. The UK, New Zealand and Australia on the other hand have negotiated rather high emissions ceilings. In addition, Australia and New Zealand are large energy consumers per capita and per unit of GDP. These countries should therefore have ample possibilities for reducing their emissions. Although the UK does not have the same high level of energy consumption, it received a rather high emission ceiling under EU burden sharing agreement. Hence, Australia, New Zealand and the UK are potential sellers of emission permits. Industry in countries that expect to trade permits may want to build experience in emissions trading as soon as possible. This will make it easier for their emission sources to join international emissions trading.

Denmark is a rather special case. The country has set itself the ambitious goal of reducing its greenhouse gas emissions by 21 per cent in the year 2010 compared to 1990. Although Denmark has rather low costs for reducing greenhouse gas emissions, it is not certain that the country can sell permits. The reason for preferring tradable permits may be explained in another way. At this moment, an intricate CO_2 tax system is in use in Denmark directed at industry (Svendsen 1998a). Since taxes are the least preferred instrument of industry, it seems that Danish industry has not been able to convince the Danish government of the usefulness of voluntary agreements. Hence, the choice of instruments is limited to marked-based instruments. Within this class, grandfathered tradable permits are clearly preferred to taxes by industry.

Although the result is in line with the theory as described above, the lack of support for tradable permits in the US is remarkable. Svendsen (1998b) shows that American industry has a preference for grandfathered tradable permits. Furthermore, there is substantial experience with tradable permits in the US. Therefore, one would expect somewhat more support for tradable permits. However, the US has not ratified the Kyoto Protocol and may very well never do so. Industry may therefore be careful not to show too much willingness to reduce emissions and not to give the impression that it is willing to take on a fixed ceiling.

International Trading Scheme In the theoretical analysis, we found that support by industry for international emissions trading depends on its positions relative to the international emissions market. Concerning how international emissions trading should take place, we found that industry will support both government and private trading and also a combination of the two. Limits on international emissions trading are rejected since they increase costs.

In their statements on the Internet, most industrial organizations express support for some system of private international emissions trading. Government trading is, however, hardly discussed. The reaction to a cap on trading is unequivocal; industry clearly rejects any restrictions on international emissions trading.

Industry supports international emissions trading mainly because of the reduction in compliance costs and because of the flexibility that the instrument brings. According to the Business Roundtable (BRT), international emissions trading can 'result in sharply reduced compliance costs, reducing the impact of limiting the levels of these (GHG) emissions' (BRT 1999). In Europe, too, these advantages of international emissions trading are brought forward. UNIPEDE and EURELECTRIC (1999a) argue that 'free and open trading can help to meet emission objectives by lowering compliance costs and by giving a strong signal, via the price of CO_2 permits, on the economic implications of an emission objective'.

When endorsing international emissions trading, most industrial organizations state a preference for trading between private entities. As the World Business Council for Sustainable Development (WBCSD) states, 'governments should foster a market in which companies can participate directly in international emissions trading and can trade credits obtained from projects' (WBCSD 1998). Hereby, the WBCSD also states a preference for JI because it emphasizes that trading should be based on projects.

The primary reason for preferring private emissions trading is that this will be more effective than government trading. The Pulp and Paper Manufacturers Federation of Australia (PPMFA) states that 'for international emissions trading to work as an efficient market mechanism, it is essential that there are a large number of potential buyers and sellers' (Cribb 1998).

According to the International Federation of Industrial Energy Consumers (IFIEC) 'the trading system would operate at company level, as only companies can deliver the agreed efficiency improvements' (IFIEC 1998).

However, international emissions trading is not always met with enthusiasm. Some organizations are doubtful about the instrument, for example, because of the lack of experience with emissions trading at the international level. The Edison Electric Institute (EEI) states that 'until provisions governing emissions trading, joint implementation and CDM are fully fleshed out, the value of these mechanisms cannot be determined' (EEI 1998). Other criticisms have also been voiced. According to the NAM, 'International emissions trading would require U.S. companies to buy "credits" from Russia or ex-Soviet bloc economies, which are really economic-growth rights, at near-monopolistic prices. This private foreign aid will be a huge additional energy tax on American business' (NAM 1999).

Only the Japanese organization Keidanren mentions government trading directly. They state that 'the idea of JI and the emissions trading scheme among governments and so on deserve consideration as approaches that provide flexibility' (Keidanren 1997), which clearly endorses government trading. In most other cases where government trading is mentioned, or even more often hinted at, it is treated as something inevitable. Many industrial organizations therefore plead for governments to allow trading between firms alongside government trading.

Industry is strongly opposed to any restrictions on international emissions trading. Several reasons are mentioned, but the most common objection is that such restrictions will increase costs of compliance for industry. This view is clearly given by the WBCSD, for example: 'Attempts to elaborate supplementarity through national ceilings on trading will increase complexity and cost. It may also erode confidence in a traded commodity relying on parties' commitment to the targets that they have negotiated' (WBCSD 1998). The European organization UNICE also expresses this view: 'it would be environmentally and economically counterproductive to seek to put arbitrary limits on the use of flexibility and trading' (UNICE 1998). Other organizations are also very clear in their rejection of caps on trading. According to the Global Climate Coalition 'We must do everything we can to minimize the damage to the economy?. For that reason, any emissions trading has to be unlimited' (GCC 1999). The EEI is very categorical in its rejection: 'there must be no quantitative or qualitative caps or limits, individually or collectively, on the use of the market mechanisms' (EEI et al. 1999). Another reason for rejecting caps on trading is provided by the Swedish industrial organization Industriforbundet. It states that restrictions on trade may jeopardize the ratification of the Kyoto Protocol by certain countries, notably the US (Industriforbundet (1999)).

The empirical findings are largely in accordance with the theory. Industry states a clear preference for international private emissions trading and rejects restrictions on international emissions trading. However, industrial organizations in many cases do not discuss whether by private emissions trading they mean permit trading, credit trading or JI. One reason for this could be that industry has no clear insight into the trading schemes and into the consequences of their choice at the national level on their options at the international level. This is in particular true for Europe where market instruments other than taxes have hardly been applied and industry mainly has experience with direct regulation through relative standards and voluntary agreements.

We expected clear support for government trading. However such support is almost never clearly stated. There is, however, an expectation that trade between governments will take place. It may be for this reason that industry does not bother to mention it. Other reasons for not stating a preference for government trading could be strategic. Most of the reasons for preferring government trading, such as the possibility to relax national abatement requirements, would not give industry a good image if they were expressed openly. Therefore, industry has every reason not to express them.

Table 9.3: Industry preferences

Organization	Location	National instrument	Int. trading scheme	Trade limits
ICCA	Global	VA	–	–
ICCP	Global	VA/permits Private	No	
WBCSD	Global	VA/permits	Private	No
WCI	Global	VA/permits	Private	No
BRT	USA	VA/permits	Private	–
EEI	USA	VA	JI	No
EPSA	USA	standards	–	–
GCC	USA	VA	–	No
NAM	USA	VA	–	–
AMEC	CAN	VA/permits	–	–
CEA	CAN	VA	–	–
CPPA	CAN	VA	–	–
FEPC	J	VA	JI	No
Keidanren	J	VA	Government	–
CEFIC	Europe	VA/credits	JI	–
e5	Europe	Permits	Permits	–
ERT	Europe	VA/permits	Private	–
Eurelectric	Europe	VA	JI	No
IFIEC	Europe	VA	JI	No
UNICE	Europe	VA/credits	Gov./private	No
UNIPEDE	Europe	VA	JI	No
VNO-NCW	NL	VA	Government	–
VBO-FEB	B	VA	JI	–
BDI	D	VA	–	–
VDEW	D	VA	JI	No
CBI	UK	Permits	Permits	–
NHO	N	Permits	Permits	–
DI	DK	Permits	Private	–
Industriforbundet	S	–	Government	No
NZBR	NZ	Permits/taxes	–	–
ESAA	AUS	Permits	–	–
PPMFA	AUS	Permits	Private	–

Notes: A dash indicates that preferences on this issue were not found.
VA = voluntary agreement
Source: Boom and Svendsen (2000b)

9.3.2 Environmental Organizations

National Instrument We showed in the theoretical analysis that environmental organizations should prefer emission ceilings or permit trading at the national level. The main advantage of these instruments for environmental organizations is that they have a high certainty of realizing the policy objective.

Environmental organizations do not, however, give a clear preference for a national instrument in their statements on the Internet. Only the Environmental Defense Fund (EDF) states a preference for a single instrument. According to the EDF, 'Mandatory, permanent emissions caps are imperative, but they will be effective only if they are practical, enforceable, and equitable. To achieve this, EDF has suggested a system based on tradeable emissions allowances' (Environmental Defense Fund (EDF) 1993).

Other organizations emphasize that more than one instrument is needed. For example, the Natural Resources Defense Council (NRDC) states that 'tax incentives must be created in order to promote mass transit and encourage industries that develop efficient technologies and renewable energy sources' and 'the US must institute mandatory limits on global warming pollution, using standards that optimize environmental performance, such as limiting the pounds of carbon emissions per unit of electricity output' (Lynch 1998). The Sierra Club Canada and the Worldwide Fund for Nature also have detailed plans containing a wide array of instruments (Comeau 1998 and WWF 1997a,b,c). The case for a diversity of instruments as opposed to only using tradable permits is most eloquently stated by the NRDC: 'Advocates of emissions trading think that you sit down at the piano and you play one emissions-trading key, and the sonata will play itself. We need to press keys for energy efficiency, and we need to play renewable energy keys. We need to press this series of keys to make houses, buildings, industry, and vehicles more efficient' (Lynch 1998).

Another feature of the statements by environmental organizations is their concentration on technical solutions to the problem of global warming. This discussion is in many cases far more important than their discussion of the choice of instruments.

So we find no clear preference for national instrument by environmental organizations. The most likely explanation for this is that they are geared to showing that emissions can be reduced with existing techniques. By doing this they put pressure on both the government and industry, which now have to explain why they do not take action to curb emissions. Because of their concentration on abatement techniques, they have neglected the issue of national instrument choice. Whether they further their interests best in this way remains to be seen. It does show, however, that environmental organizations are more interested in reducing emissions than in how this is done.

International Trading Scheme The theoretical analysis showed that environmental organizations are opposed to international emissions trading. The main reasons for this are that they want to ban trade in hot air and trade with countries without proper institutions for monitoring and enforcement of environmental policy and because they prefer abatement to be done nationally so as to spur research and development of new abatement technologies. If international emissions trading is unavoidable, environmental organizations prefer government trading because this gives the best possibilities to limit trade.

As with instrument choice at the national level, we do not find a clear preference for an international emissions trading scheme. The EDF supports the flexibility mechanisms of the Kyoto Protocol and gives a preference for permit trading, although this is not stated very strongly (Environmental Defense Fund (EDF) 1993, 1998). The Sierra Club is the only environmental organization that clearly prefers JI (Corbett et al. 1997 and Rolfe (1998)). The reason for this is that only credit trading will prevent trade in hot air. Other environmental organizations do discuss international emissions trading but give no preference for any scheme. Some organizations can even see some merit in emissions trading, but they also see 'many ways in which a global emissions trading regime could go badly wrong' (Greenpeace 1998).

Many environmental organizations view international emissions trading as a loophole that enables industrialized countries to 'avoid taking domestic action ... and continue on a path of dangerous emissions. This is not only iniquitous but it is also ecologically ineffective' (Climate Action Network (CAN) 1999). The WWF had already stated before the negotiations that the Kyoto Protocol should 'not include an emissions trading system unless much stronger reduction targets than those currently proposed by industrialized countries are adopted' (WWF 1997d). International emissions trading is even rejected in principle as 'unfair because it rewards large industrialized polluters without compensating poorer nations which will suffer the worst effects of climate change' (WWF 1998).

In general, environmental organizations prefer a cap on emissions trading. One reason for this is that it reduces the possibility of trade in hot air. Hence, restrictions on international emissions trading will result in lower aggregate emission levels. However, another reason also seems to be very important. According to Friends of the Earth (FOE), 'the majority of emissions reductions must be achieved through domestic, verifiable emission reductions' (Friends of the Earth 1998). The reason for this is that 'it is essential to provide a clear signal to begin with redirecting investments to environmentally sustainable technology' (Friends of the Earth 1998). Another reason is that 'placing a limit, or "cap", on the proportion of Parties' Kyoto targets that can be achieved abroad will promote new technologies for domestic reductions and minimize trading in hot air' (WWF 1999).

Only the EDF rejects restrictions on emissions trading (Environmental Defense Fund (EDF) 1998). Several reasons are given for this. Caps on trading will increase compliance costs for industry without giving any additional benefit to the environment. Furthermore, contrary to the other environmental organizations, the EDF argues that caps will lead to less innovation. The EDF also sees caps on trading as superfluous because a large part of emission reductions will be realized domestically anyway.

This section that environmental organizations in general reject international emissions trading. Most organizations call for a limits on trading. One reason for this is to limit the trade in hot air. This would then lead to lower emission levels. Besides this reason for limiting trade, it is also

Table 9.4: Preferences of environmental organizations

Organization	Location	National instrument	Int. trade	Trade limits	Int. instrument
Greenpeace	Global	–	No	Yes	–
CAN	Global	–	No	Yes	–
WWF	Global	–	No	Yes	–
FOE	Global	–	No	Yes	–
EDF	USA	Permits	Yes	No	Permits
NRDC	USA	Standards	No	–	–
Sierra Club	USA/CAN	–	No	Yes	JI

Notes: A dash indicates that preferences on this issue were not found.
Source: Boom and Svendsen (2000b)

argued that such a limit will spur technological innovation. Only the EDF is against limits on trading. According to them, limits lead to higher costs and to less innovation. The overall results on environmental organizations are summarized in Table 9.4.

9.4 Conclusions

Interest groups are divided on the issue of international emissions trading. Industry supports it in general, while environmental organizations reject it, and labor unions and the environmental bureaucracy take an intermediate position. Also on how international emissions trading should be organized interest groups diverge in opinion.

For industry, international emissions trading will lead to higher profits, either through lower abatement costs if the international emission quota price is below the national price, or through the proceeds from quota sales on the international market. However, there are situations where industry does not unanimously support international emissions trading. If there is a national emissions trading scheme, either permit or credit, connection to the international market may lead to losses, either because a buyer of quotas now has to pay a higher price, or because a seller receives a lower price than in the domestic market. Industry supports both private and government trading and would like to see a combination of the two as long as the government is buying quotas. International emissions trading should not be limited because such limits increase abatement costs for industry

Environmental organizations reject international emissions trading because they are concerned that it will deteriorate the overall emission target and research and development of new abatement technologies. The problem of hot air means that total emissions will be higher with emissions trading than without. Furthermore, sellers may not comply with their revised abatement commitment after the sale of quotas, thus inflating total emissions even further. If instead, countries could only realize their emission targets domestically, this would lead to more R&D investment in abatement technologies, eventually resulting in lower abatement costs. This would then make it possible in future commitment periods to reduce emissions even more. If international emissions trading cannot be avoided, environmental organizations prefer government trading with limits both in the form of caps on the quantity that can be traded and limits on which countries to trade with.

Labor unions support international emissions trading as long as this leads to lower costs to industry and thereby to higher output. This will be the case when the industry is a buyer of quotas. In itself, it does not matter whether international emissions trading takes place between firms or governments.

Also the environmental bureaucracy only supports international emissions trading when industry is a buyer of quotas. Their reason is that this will make it easier for industry to comply with the national target. The bureaucracy would like to have some measure of control with international emissions trading and would like domestic industry to make some abatement efforts on their own. Hence, they prefer a cap on the total amount bought and would like to have control over the choice of trading partners. This all points to government trading, although restricted private trading is supported as well.

Empirical evidence on interest group preferences could only be collected for industry and environmental organizations. The empirical evidence presented largely supports the theoretical analysis. It shows that industry prefers voluntary agreements or permit trading at the national level and JI or private trading at the international level. Government trading is not mentioned very often, but this may be caused by strategic considerations. Caps on trading are rejected categorically.

Environmental organizations show no clear preference for a national instrument or an international emissions trading scheme. They mostly concentrate on technical solutions to reduce emissions, showing that abatement is possible at reasonable cost. This indicates that environmental organizations are only interested in reducing emissions and not so much in the regulatory framework within which this should be done. Their support for a cap on trading also fits within this line of reasoning; it will reduce hot air trading and force countries to take domestic action.

International emissions trading is not unanimously supported, sometimes not even by industry. Implementing international emissions trading will therefore be difficult and it is likely that some limits will be placed on trading. These limits will especially be on who to trade with and perhaps also on how much can be bought abroad.

Chapter 10

Conclusions

The aim of this book is to analyze the political acceptability of international emissions trading. Two main questions can be posed in this respect. First, is it acceptable for countries that international emissions trading is made possible or would they rather see international control of global emissions without such trading. Second, when international emissions trading is allowed which type of emissions trading scheme is preferred by countries.

In the first part of the book (chapter 2 to 7) we have assumed that the objective of the government is to maximize national welfare. It then follows that whether international emissions trading as such is acceptable to countries depends on how this affects their welfare. If international emissions trading is implemented, the most preferred instrument is the one that gives highest national welfare. In chapter 2 the first question has been discussed. We have shown in chapter 2 that when countries know that international emissions trading is going to be a part of an international agreement, they will alter their abatement commitments. This will happen when countries behave non-cooperatively, that is, try to maximize their own national benefits, but also when they act cooperatively, that is, when they take the effect of their actions on other countries into account when setting their emission ceiling. Basically, a potential buyer of permits will set a lower emission ceiling since it now can purchase emission reductions at a lower price in the market than it could at home. For a potential seller, the opposite occurs.

The effect on total emissions depends partly on the setting. The major result of the analysis is that in certain settings international emission control with international emissions trading will make that total emissions are higher than control without emissions trading. As a consequence, a country may end up with lower welfare if international emissions trading is allowed and for that reason it will prefer international emission control without the option of trading emissions. Specifically, the effects of international emissions trading on total emissions are the following. If countries behave non-cooperatively and no country has market power total emissions always increase. For this situation to occur, it is necessary that there are enough identical countries with lowest abatement costs, which is not a very realistic assumption. If countries are heterogeneous, it turns out that at least one country must have market power. This country is a seller and therefore has monopoly power in the market for permits. If all countries, sellers and buyers, have market power, total emissions can increase or decrease as a result of international emissions trading. Even when countries behave cooperatively, we find that emissions trading can lead to higher total emissions. The effect on total emissions combined with the change in abatement costs because of the shift to international emissions trading determines the overall effect on welfare. International emissions trading may increase or decrease a country's welfare, where a decrease is more likely when emissions trading leads to higher overall emissions. If it leads to lower welfare, international emissions trading will not be acceptable for a welfare maximizing government: after all, the country would be better off without emissions trading. However, even if international emissions trading makes some countries worse off compared to the case without trading, international emissions trading may still be implemented, since no country can forbid other countries to trade emission quotas between them.

The second major question researched in the book was: when international emissions trading is going to be an element of an international environmental agreement, what type of emissions trading scheme will be preferred by a participating country. In chapter 3 the different options from which a choice can be made have been presented and their strengths and weaknesses discussed. The basic alternatives are government trading and private trading. Government trading amounts to a direct transfer of assigned amounts between governments; the commitments in terms of emissions ceiling of the trading countries change accordingly. These changes in commitment will have to be reflected in changes in domestic policy, for example setting emission standards which are more stringent (for a seller) or less so (for a buyer), which will take much time if some policy already has been implemented. Because of the large costs of changing policy and large transaction costs per trade, government trading is likely to be infrequent, involving a large amount of emission quotas and to take place either before national policy is set, or at the end of the commitment period when the effect of national policy on national emissions becomes clear and assigned amounts can be purchased if it looks that the country will not be able to comply, while assigned amounts can be sold if total emissions are going to end up below the emission cap. A major advantage of government trading is that it is compatible with all forms of domestic environmental policy and that it gives the government full control over trading. However, because trade will be infrequent, with relatively few actors involved, government trading will not be fully efficient, although it will lead to cost reductions compared to no trading.

Private trading refers to emissions trading between private entities. These will most often be emission sources, but others can trade too. Private emissions trading will lead to continuous trading, so that a market price for emission quotas arises. Firms can easily observe this price and compare it to their own marginal abatement costs to see whether they should sell or buy emission quotas. However, emissions trading between private parties at the international level can not be combined with all possible instruments at the national level. Basically, international private emissions trading amounts to a linking of national emissions trading schemes so that domestic emissions trading becomes a precondition for international trading.

There are two basic possibilities for private trading schemes; permit and credit trading. The difference between permit and credit trading is how the emission target for the individual emission source is set. With permit trading, the basis for the scheme is a ceiling on total emissions which is divided in permits that are made tradable. With credit trading, the basis for the scheme is formed by defining some emission standard other than a ceiling on emissions. The emission target for the individual source is then calculated using the emission standard. Credits can then be created and sold if a firm can stay below the emission target.

There are several ways to organize a permit trading scheme. An obvious choice is to distribute the permits over the polluters and allow them to trade. This is known as a downstream scheme. The advantages are that there are many traders, so that a market in permits will develop. This ensures full efficiency. Furthermore, distributing the permits to the polluters makes it more acceptable to grandfather the permits, so that the scheme becomes more acceptable to the regulated emission sources. A disadvantage will be that there are many emission sources for CO_2, so that there will be high monitoring and control costs if all sources are to be included. These costs are assessed as being so high that a pure downstream system covering all sectors is deemed to be not feasible. Another possibility is to distribute the permits to the suppliers of fossil fuels, a system known as an upstream scheme. The suppliers of fuels will pass the price of permits on to the consumers, so that they in effect pay a carbon tax. With an upstream scheme, the number of control points is kept low, so that administration costs are low and virtually all CO_2 emissions can be covered. However, there will be few traders, so that a fully developed market may not arise and some traders may have market power. Another problem is how the permits should be distributed. Grandfathering would amount to a large transfer of rents to fossil fuel companies, which is unlikely to be politically acceptable. However, auctioning the permits will meet stiff resistance from the suppliers. Hence, the political acceptability of an upstream system is rather low. There is however another possibility that combines aspects of upstream and downstream trading. In this alternative design, permits are distributed to emission sources, big and small, but compliance is monitored at the level of the suppliers. Basically, with every purchase of fossil fuel, permits have to be handed over to the supplier (or distributor) covering the carbon content of the fuel. In this way, the permits end up in the hands of the suppliers, where it is relatively easy for the government to monitor compliance. The scheme is largely self-enforcing since sellers have an interest to receive the right amount of permits from buyers. This scheme makes it possible to distribute the permits for free to the polluters, thereby enhancing political acceptability. Furthermore, there will be many traders, so that an efficient market is ensured.

With credit trading, an emission standard has to be defined. In most cases this will be a limit on emissions per unit of an input or output. In this book we have assumed that credit trading is always based on a standard that limits emissions per unit of output. The emission target for the individual source is then defined as the relative standard times output. Firms that expect to stay below this target can sell emission reduction credits to firms where compliance is very costly. The main advantage of credit trading is that the political acceptability of such a scheme will be high. The design gives firms maximum flexibility in that emissions can be increased as output is increased and firms can trade credits. Furthermore, the initial distribution of the right to pollute is for free. For other actors, credit trading has the advantage that it builds on existing regulation and therefore is only an incremental change from current practices. Disadvantages are that credit trading is inefficient and not environmentally effective. Another problem is that credit trading cannot cover all emission sources since some output is needed to be able to define a relative standard. This excludes households.

A formal analysis of permit and credit trading was given in chapter 4. Here, we compared the performance of the two schemes with respect to welfare and industry structure under both perfect and imperfect competition in a national setting. Furthermore, we analyzed the performance of a combined scheme where one sector is regulated through permit trading and another through credit trading, while trade of emission quotas between the two sectors is allowed. The basic differences between permit and credit trading are that credit trading leads to higher total output, higher total and marginal abatement costs and a higher number of firms in the industry than permit trading. The reason for this difference is that credit trading works as a tax on emissions combined with a subsidy on output. Every additional unit of output produced by the firm gives it the right to increase emissions by the amount of the relative standard. Since emissions are valuable to the firm, this amounts to a subsidy. However, this constellation leads to higher marginal abatement costs since the same total emission ceiling has to be reached while output is larger. The implicit subsidization of output in the credit trading scheme has consequences for welfare. Under perfect competition, output is too large in a credit trading scheme, and hence credit trading leads to lower welfare than permit trading. A welfare maximizing government should therefore prefer permit trading, at least as long as there is no international trade. With imperfect competition, this picture may change. Imperfect competition leads to lower than optimal output levels. What is called for if the sector also pollutes, and imperfect competition cannot be transformed in perfect competition by way of competition policy, is a combination of a tax on emissions and a subsidy on output. This is exactly what the credit trading scheme does. However, the implicit output subsidy in a credit trading scheme is only at the optimal level by accident and may be too large in which case it leads to too high production levels. Hence, credit trading only improves on the outcome with permit trading if it does not lead to too much output. A welfare maximizing government will therefore prefer credit trading to permit trading when the regulated sector is characterized by imperfect competition and credit trading does not lead to too high output.

It is possible that two sectors or countries are regulated through different trading schemes, one through permit and the other through credit trading. It is then possible to combine the two markets by allowing the transfer of credits to the permit sector and vice versa. As mentioned credit trading leads to higher marginal abatement costs than permit trading. The result is that with separate markets and all else equal, the credit price is higher than the permit price. As a consequence, permits will flow to the credit sector when the two schemes are connected. This will stimulate output in the credit sector and increase the discrepancy in terms of output and abatement effort between the two sectors. The even larger overproduction in the credit sector and the lower output in the permit sector means a welfare loss, at least under perfect competition. However, the sale of permits to the credit sector makes that abatement effort increases in the permit sector where marginal abatement costs are relatively low, while abatement decreases in the credit sector where marginal abatement costs are relatively high. The result is that total abatement costs will go down. Whether combining the two sectors leads to higher welfare than keeping them separate depends on whether the savings in total abatement costs exceed the welfare loss due to higher production in the credit sector. It should be borne in mind though that under perfect competition welfare would be even higher if both sectors were regulated through permit trading. Under imperfect competition the effects of combining the two schemes are the same as under perfect competition. However now the output increase in the credit sector may also lead to a welfare increase, thus enhancing the positive effect of lower abatement costs.

A question that has not received much attention in the literature is how smooth the transition from the equilibrium without environmental regulation to the equilibrium with regulation is. If a transition to regulation leads to more volatility under one instrument than under other instruments this would be seen as a negative factor for that instrument. The main reason for this is that volatility in markets can lead to efficiency losses in that the market has to adapt all the time. In general, it is implicitly assumed that the industry will move to the new equilibrium and the transition period and its problems are simply neglected. In chapter 5 we have focused on the transition period to see whether the transition is smooth and whether an equilibrium is always reached under all circumstances. To see whether volatility can arise, we constructed a discrete time model with production and emission control through a permit scheme, a credit scheme, or firm emission ceilings where the government can behave myopically. This means that the government sets its policy in the current period based on sector output and number of firms in the previous period, thereby assuming that neither output, nor the number of firms will change in the following period. For permit trading this behavioral assumption does not alter government decisions. A total limit is set and the permits are grandfathered to incumbent firms in each period. For credit trading this means that the relative standard is revised in every period, simply by dividing the total emission limit by total output in the previous period. For absolute standards, the government adjusts the firm emission ceiling by dividing the total emission ceiling by the number of firms in the previous period. For firms we have assumed that there is no time lag in adjusting emissions and production to new policy, but there is a time lag in exit and entry: firms' entry or exit decision depends on profits and government policy in the sector in the previous period. This type of model is hard, if not impossible, to analyze analytically. Therefore, some numerical simulations were done with different price elasticities of demand for the good and with different abatement costs. The results are based on these simulations. We found that when both the government and firms behave in the manner just described, the introduction of environmental regulation can lead to persistent volatility under credit trading, but not under permit trading. This is especially the case when demand for products is elastic. This outcome holds under both perfect and imperfect competition. Under perfect competition, a higher speed of adjustment by firms, through entry and exit, may exacerbate volatility when product demand is inelastic and mitigate it when demand is elastic.

Although adjustment of environmental policy does take place in reality, it does not commonly happen on a regular basis. Therefore, a more realistic scenario may be the one where the government sets certain standard for the first period and does not change this standard over time. We also modeled this case. Here, we assumed that the government has perfect foresight and sets the standard at its long-run equilibrium level. The result is that the transition to the new equilibrium is always smooth under all instrument, at least with perfect competition, even though the transition period could be longer than under myopic behavior by the government. However, under imperfect competition, we found that even a constant standard can lead to persistent volatility in the market under credit trading. This is due to the time lag in entry or exit of firms combined with the fact that firms assume that their rivals will produce the same amount as in the previous period and adjust their own output accordingly.

The result is that credit trading may be a less attractive instrument because it may lead to persistent volatility in the market if the assumptions of the underlying model are fulfilled. This will especially be a problem if the government wants to pursue a policy where it regularly adjusts the standard until it reaches the optimal level. In most cases however, governments set a fixed standard and only adjust it when real emissions are very far off the target, otherwise, over- or undercompliance is just accepted. As we argued above, it is under imperfect competition that credit trading may lead to higher welfare than permit trading. But precisely under imperfect competition even a constant relative standard may lead to persistent volatility, which makes this a less attractive instrument in this case.

So far we have left aside the possibility that firms trade goods internationally. In chapters 6 and 7 that assumption was dropped and we have analyzed how the fact that governments of countries have market power on international goods markets may affect the optimal instrument choice for a welfare maximizing government. Specifically, we investigated which type of national instrument would lead to highest welfare and whether it would be welfare improving for countries to allow their firms to participate in international emissions trading. In chapter 6, we have analyzed the case where the sector regulated is perfectly competitive. However, the government has market power and can through its environmental policy affect output and thereby the price on the international market. Here it is important that there is a difference between the output of the regulated industry under credit trading and permit trading. In chapter 7 we have presented the case where there is a duopoly in the product market, with each producer located in a different country. Output is consumed in both producer countries and in a third market.

In both cases, countries that can influence the world market price of a good and aim at maximization of national welfare have an incentive to choose their national policy strategically. That is to say, governments have an incentive to alter the output of their industry if they have the possibility to affect world prices of goods. In which direction they want to alter prices depends on whether the industry is competitive or not and on whether the country exports or imports the good. Furthermore, in some cases countries are better off when they do not allow their sector to participate in international emissions trading. With international emissions trading there are two effects that have to be taken into account. First, permit trading leads to less output than credit trading. Second, when the international price of emission quotas is higher than the domestic price, the country becomes a seller of quotas. This will make that it will abate more, resulting in lower output. When the country becomes a buyer of quotas, domestic output will increase when the country allows international emissions trading for its firms.

Under perfect competition, when a country exports the good, the country's welfare is maximized by increasing the producer surplus even though this diminishes the consumer surplus somewhat. This means that the government wants to reduce output to raise the world price of the good and thereby increase firm profits. In this case, the best choice of domestic instrument is permit trading since this leads to the lowest output level. When the country imports the good, welfare can be increased by increasing the consumer surplus somewhat at the expense of the producer surplus. This gives a preference for credit trading. However, credit trading can also lead to too large an increase in output, turning the importer into an exporter. In those cases, the country prefers permit trading.

In contrast, when there is a duopoly in the goods market, the government wants to increase the output of its firm, no matter whether the country imports or exports the good. The reason for this is that an increase in output by the domestic firm leads to a decrease in production by the foreign firm, so that the domestic firm captures market share and increases its profits at the expense of the foreign firm. The more of the product is consumed domestically, the stronger the incentive to increase output becomes since higher output increases the consumer surplus. Since credit trading leads to higher output than permit trading, the government may prefer this instrument. However, credit trading can also lead to too high production, in which case the country is better off with permit trading.

Whether a country wants to allow its firms to participate in international emissions trading depends on the world price of emission quotas relative to the domestic quota price and to the direct gain from emissions trading. The outcome for perfect competition is again somewhat different from the one for imperfect competition. We first look at the case where the sector is perfectly competitive. When the country becomes a seller of quotas, this will lead to a reduction in output. This increases welfare when the country is an exporter of the good, both because it increases profits from exporting output and because it gives a profit from selling emission quotas. When the country is an exporter of the good and becomes a buyer of emission quotas the two effects work in opposite direction. The country's and thereby total output will increase so that profits decrease too. However, the country still gains from international emissions trading because of lower abatement costs. Whether welfare increases from a shift to international emissions trading then depends on whether the direct gain from emissions trading is larger than the fall in monopolistic profit on the product market. If welfare does not increase, the country is better off by not joining international emissions trading. If the country is an importer of the good, the reverse holds in general. In this case, it will generally gain when it becomes an importer of emission quotas and it is uncertain whether it gains when it becomes a seller of emission quotas. Also here, the country may prefer not to join international emissions trading.

When there is imperfect competition, the country is generally better off when its output increases, so that it wants to join international emissions trading when it becomes a buyer of emission quotas. However, this may also lead to too large an increase in output, but only when it uses credit trading. In that case, it may prefer not to join the international emissions quota market. On the other hand when it becomes a seller of emission quotas, firm profits and consumer surplus will decrease which has a negative effect on welfare. The country however still gains from the sale of emission quotas. Whether it then wants to join international emissions trading depends on whether the latter gain is larger than the loss in profits and consumer surplus. If this is not the case, the country prefers not to join international emissions trading.

We have also presented an analysis of countries' equilibrium instrument choice in a two country setting. Here, we have shown that a country's choice of instrument depends on the instrument choice by the other country. The reason for this is that instrument choice influences a country's reaction to foreign changes in output. One consequence of this is that under imperfect competition, identical countries may prefer different instruments for international emissions trading in the Nash equilibrium for instrument choice.

In chapters 3 to 7, we have assumed in the analysis that countries maximize welfare. Acceptability of an instrument of environmental policy and international emissions trading then depends on whether it increases welfare. The best instrument is the one that gives highest welfare and countries will join international emissions trading when that increases welfare. Which type of emissions trading gives highest welfare depends on several factors, such as market structure, behavior of government and firms, whether the country has market power on the international market for goods and the international emission quota price relative to the domestic one.

It is however doubtful that a decision on which instrument to implement in environmental policy is based solely on welfare considerations. Therefore in chapters 8 and 9 we turned to public choice theory for an explanation of instrument choice. The underlying theory in these chapters is that interest groups try to influence policy outcomes. This can be done by supporting certain politicians or parties during election campaigns so that the politicians have a higher certainty of being (re)elected. In return, the interest groups expect favorable policies during the turn in office of 'their' candidate. Another method for gaining influence is by providing information to legislators. Legislators typically make their decisions under uncertainty about the costs and benefits of certain policies. Interest groups are often relatively well informed on these issues and are able to influence decisions by selectively providing information. In chapters 8 and 9 we have not dwelled on how interest groups affect government decisions, but analyzed the preferences of these groups for national instrument of environmental policy and for international emissions trading scheme. Specifically, we analyzed the preferences of shareholders, firm managers, the environmental bureaucracy, labor unions and environmental organizations for both national instrument and international emissions trading scheme. Furthermore, we found empirical evidence on preferences by industry and environmental organizations on both issues.

In chapter 8 we started by analyzing interest group preferences for national instrument. As already mentioned earlier, the choice of national instrument affects the options for international emissions trading. International emissions trading between private entities is basically a linkage between national emissions trading schemes. Therefore, international private emissions trading can only be an outcome when emissions trading in some form also is the outcome at the national level. For industry, preferences are a mix of the preferences of shareholders and managers. Shareholders want high stock value, which is attained by tradable permits, while managers want large scale of production combined with a high certainty of firm survival after the introduction of regulation. This points to voluntary agreements or credit trading. The main reason for choosing these three instruments is that they allow for large cost savings compared to traditional forms of regulation. Which of the three instruments is preferred depends on whether shareholders or managers have most influence. Labor unions prefer high employment. Assuming that this is associated with high levels of production, labor unions will prefer credit trading or voluntary agreements. The environmental bureaucracy has some more complex preferences, including certainty of achieving the emission target, high input of bureaucratic labor and direct control over polluters. However, there is a group of bureaucrats that values (indirect) control over total pollution higher than direct control with polluters. In the end, bureaucrats may prefer voluntary agreements, credit trading or grandfathered tradable permits. Environmental organizations mainly have a preference for low pollution levels and for certainty to achieve the emission target. Tradable permits give high certainty of achieving the target and give costs savings to industry, making it possible to achieve lower emission levels while still giving lower costs to industry. Hence, environmental organizations prefer tradable permits, but want the permits to be auctioned, so that the right to pollute is not granted for free. The empirical evidence largely supports the theoretical analysis. Industry shows a preference for voluntary agreements or permit trading. On the other hand, only one environmental organization directly supports permit trading, while the other organizations do not state a preference for any instrument, but emphasize the possibilities for reducing emissions.

Our theoretical analysis in chapter 9 predicted that interest groups are divided on the issue of international emissions trading, both on whether or not international trading should be allowed and on how it should take place. Furthermore, there is disagreement on whether or not there should be limits on the total amount traded and on whom to trade with. In general, industry gains from international emissions trading. However, some groups of firms or sectors may lose. Hence, industry will not always unanimously support international emissions trading. The international emissions trading scheme supported by industry depends on the national instrument. If voluntary agreements are implemented, then only government trading and joint implementation (emissions trading between industrialized countries on the basis of projects) are possible, which are both supported. When permit or credit trading are implemented, industry supports private international emissions trading. Industry would in this case also support the purchase of emission quotas by the government, provided that the quotas are handed to industry for free. The empirical evidence largely supports the theoretical analysis. We found support for joint implementation and private trading at the international level. Support for government trading was also voiced. Since limitations on trading only add to costs, industry rejects any such limitations.

For the environmental bureaucracy and labor unions, support for international emissions trading depends on whether the country becomes a buyer or seller of quotas. If it becomes a buyer, output and thereby employment will increase, which is a preferred outcome by labor unions. Furthermore, buying quotas means that it is easier for industry to realize the national emissions target so that environmental bureaucrats will support international emissions trading in this case. For labor unions, it does not matter much whether emissions trading takes place as government or private trading. The environmental bureaucracy would however like to have some control with international emissions trading. Reasons for this are that it wants to prevent trade in hot air and trade with nations that do not monitor and enforce environmental policy effectively. Furthermore, they would like domestic industry to make an effort in reducing emissions at home. Therefore, they would prefer a cap on the total amount of emission quotas that can be bought abroad. These limitations can most easily be implemented through government trading. However, private trading with trading partners from a limited number of countries that adhere to strict monitoring and enforcement standards and that do not have hot air is acceptable too. Both labor unions and the environmental bureaucracy will resist international emissions trading when domestic industry becomes a seller of quotas.

For environmental organizations, any form of emissions trading presents a loophole for industrialized countries not to have to reduce emissions at home. They would prefer it if all industrialized countries implemented policy such that the national emission targets were realized domestically. This would spur research and development of abatement technologies so that emission reduction goals can become more ambitious in subsequent commitment periods. Trading in hot air is rejected because this would increase total emissions. Hence, environmental organizations do not support international emissions trading. If such trading is inevitable, they would prefer government trading so that it is easier to limit emissions trading. Also here, the empirical evidence largely supports the theoretical analysis. Most environmental organizations reject international emissions trading and would like limits on trading if it is allowed anyway. However, they do not state a preference for any instrument, neither at the national, nor at the international level.

In all, we can conclude that support for international emissions trading is not unanimous. Since some countries may lose from emissions trading they would rather not have it allowed at the international level. Furthermore, if it is allowed, some countries may not let some of their sectors participate in international emissions trading for strategic reasons. The choice of emissions trading scheme also depends on several factors. If the sector is characterized by imperfect competition, the government is more likely to use credit trading than when the sector is perfectly competitive. When there is international trade in goods and the country has market power on the goods market the optimal choice of instrument depends on how much the country consumes of the good and on whether it becomes a seller or buyer of emission quotas in the international market. Finally, the preferences of interest groups, especially of industry, are influential in the decision which instrument to adopt and whether or not to allow international emissions trading.

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